Chapter 8
A Resource Organization Model for Ubiquitous Learning in a Seamless Learning Space

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Abstract The proliferation of advanced learning technologies, such as integrableware, learning object, and learning design, have prompted the development of strategies to enhance the semantics of learning resources. Such strategies are characterized by the sharing of procedural information (posts, notes, questions, assignment, etc.) during the learners' learning process, the perpetual evolution of resource content via collaborative editing, and the creation of a new resource construction mode based on Web 2.0. In this paper, a novel learning resource framework known as "learning cell" is proposed. This framework is intended to enable generative, evolving, intelligent, and adaptive learning resources in future u-learning. Learning cell provides a design model for future seamless learning spaces supported by pervasive computing technology.

Introduction

With the development of pervasive computing (Weiser 1991) and sensor networks, the digital space is increasingly converging with the physical space. This convergence gives rise to a ubiquitous information space that covers both the real world and virtual world. Thus, a seamless learning space (Chan et al. 2006) can be constructed to enable ubiquitous learning (u-learning). Indeed, learning processes are becoming increasingly context related and human based, enabling opportunities of collaborative and lifelong learning.

However, the emergence of new technological environments alone does not necessarily facilitate a good learning performance. Effective learning is inseparable from well-constructed learning resources. While current research on seamless learning has mainly focused on conceptual models, context computing technologies, and

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supportive environments (Li et al. 2005; Hong and Cho 2008; Tan et al. 2011), we as a field need to create new schemes of resource organization to make sure that learning resources are available anywhere and on demand and can address the needs of u-learning. Existing learning technologies focus on the sharing of learning resources in stand-alone platforms. The sustainable development and evolution of learning resources, the dynamic and generative connections among learning resources, and the dynamic relationships between learners and teachers via learning resources are overlooked. Following the development of integrableware (Li 1997), learning object (ADL 2000), and learning activity (IMS 2003), enabling co-construction and sharing of u-learning resources have become a core research focus among scholars.

Effective ubiquitous learning relies upon the creation of an intelligent seamless learning space. The basic elements of such an environment consist of a communication network, context-aware intelligent learning terminals, learning resources, and education cloud-computing services. The existing single-point-centralized storage and hierarchical directory organization of learning resources cannot meet the needs of pervasive, context-aware, and timely learning spaces (Yu 2007). New demands and challenges are proposed to adapt to u-learning:

1. U-learning requires contextual and adaptive learning resources. Seamless learning spaces would support the individualized needs of learners and supply recomposed learning resources that are adaptable to different learning terminals.
2. U-learning requires a large amount of learning resources. To provide ubiquitous and on-demand learning resources, u-learning needs an open and distributed resource model that enables everyone to construct and obtain learning resources. The pieces of contribution that learners made can develop into an unlimited extensible resource chain, which in turn satisfies the extensible and personalized demands for future learning activities.
3. U-learning requires evolving learning resources. Ubiquitous learning resources should be in real time to reflect the latest developments in related areas and meet the actual real-time needs of learners. U-learning needs to keep track of information generated during the learning process, which serves as nutrients for the evolution of resources and reflects the history of knowledge construction. That is, learning resources should evolve during the process of learning by absorbing the collective wisdom of learners. The traditional static and closed organization of learning resources need to be changed into one that is dynamic and open to ensure the self-evolution of learning resources.
4. U-learning requires learning resources that are integrated with learning activities. Learning does not solely consist of obtaining new information. It also requires effective internalization by providing learners a chance to participate in learning activities.
5. Above all, u-learning requires "human" resources and the sharing of social cognitive networks. Interaction in u-learning is not solely restricted to the interaction between learners and materialized resources but also includes participation in learning processes. Here, materialized resources are viewed as communication media for learners to take in collective wisdom, construct social cognitive networks, and obtain sustained channels to acquire knowledge.

In response to the above demands, this paper proposes a new scheme—learning cell—to describe and package learning resources (Yu et al. 2009). Learning cell is a new model to organize and share learning resources to support the construction of a seamless learning space.

Learning Cell Framework

Concept

Learning cell is a digital learning resource characterized by generative, open, self-evolving, connective, social, micromation, and intelligent features. Learning cell adopts dynamic elements and structure as well as cloud storage to adapt to u-learning. The meaning of "cell" is multifold:

- Component
  Components reflect the standardization, micromation, reusability, and integrality of learning cell. From this perspective, the design concepts of learning cell and learning objects are similar.
- Initial
  Learning cell would experience a development process during which it would be initialized, grow, strengthen, and increase its durability. Learning cell changes during the use process rather than remain unchanged. The evolving and germination characteristics of learning cell distinguish it from learning object.
- Neuron like
  Learning cell can perceive environments, adapt to terminals, and generate rich connections. The connections between learning cells and humans form social cognitive networks. When these networks grow to a certain scale, the social intelligence aspect takes effect, which also serves as an essential distinction between learning cell and learning object.

Learning cell is advanced mainly by introducing the temporal dimension and interpersonal cognitive networks into learning resources. Learning resources are no longer static, but grow over time. Information is stored and updated during the evolution, including version updates, historical records, and procedural information (posts, notes, questions, assignment, etc.). Relationship networks are constructed among participating persons as well as between knowledge and persons. These networks not only help students with their knowledge construction but also aid in sharing collective wisdom during the process of knowledge evolution. Learning cell provides learners with resources related to learning content; moreover, it provides a series of content-focused activities, tools, and social networks. As a result, learning cell is a channel that supplies learners with sustainable information and knowledge.

U-Learning Process Based on Learning Cell

As shown in Fig. 8.1, u-learning can generate a seamless learning space via the coordination of cloud-computing and multimedia technologies.

Whenever users encounter problems or become interested in something, their needs in the particular context can be perceived by the intelligent terminals and sent to educational cloud-computing platforms with pervasive communication networks. The platforms would perform a search, computation, and transformation according to the demands of users and individualized information to select the appropriate learning content for the use and attach the content with learning services and knowledge networks. Learners would be able to contact other learners interested in the same content, editors, and even experts to form learning communities, where they not only obtain the most authoritative knowledge in the field but also build relationships with the experts. This learning mode is not an image of traditional learning in classrooms with one teacher and many learners, but a type of 1:1 or even n:1 learning, in which many authoritative experts as well as collaborators serve as teachers for one learner.

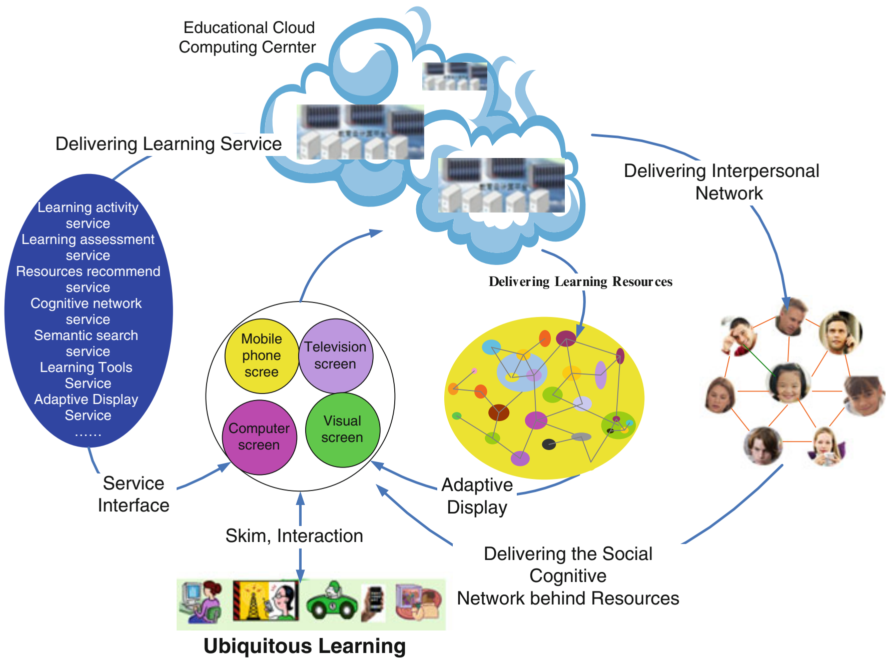

Fig. 8.1 The ubiquitous learning process based on learning cell

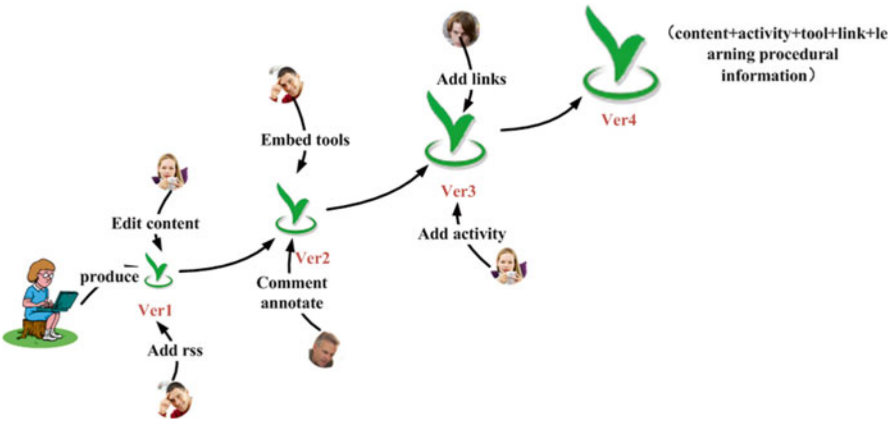

Fig. 8.2 Content evolution of learning resources

Core Features of Learning Cell

To further develop learning object and learning design specifications, learning cell features the following three unique properties:

1. It proposes a semantic-based aggregation model that controls the orderly evolution of resources according to semantic information.

Content is the key component of learning resources. An open-content organization enables multiple users to collaboratively create and edit content, which allows this content to be updated and developed (see Fig. 8.2). Users first generate learning resources and invite collaborators to edit the open content. As the content evolves, more users familiarize themselves with the content and add comments and annotations to it. With time, the content is updated as the collective wisdom of users grows until a high-quality version is generated that satisfies the demands of learners. At present, most open content evolves via collaborative editing, and a version control mechanism is used to protect the content.

The most important distinction between learning cell and learning object or SCORM-based online courses is the application of a semantic network and ontology technology, which causes learning cell to behave like an organism that grows and evolves via the control of the internal "gene." Besides as an independent learning unit, each learning cell could serve as a node in resource networks that would connect with other nodes according to certain rules (Fig. 8.3). Learning cell supports the semantic-based network aggregation model, which is different from the hierarchical aggregation model. It can aggregate different learning materials into learning cells as well as different learning cells into even bigger knowledge groups or knowledge clouds (Fig. 8.4).

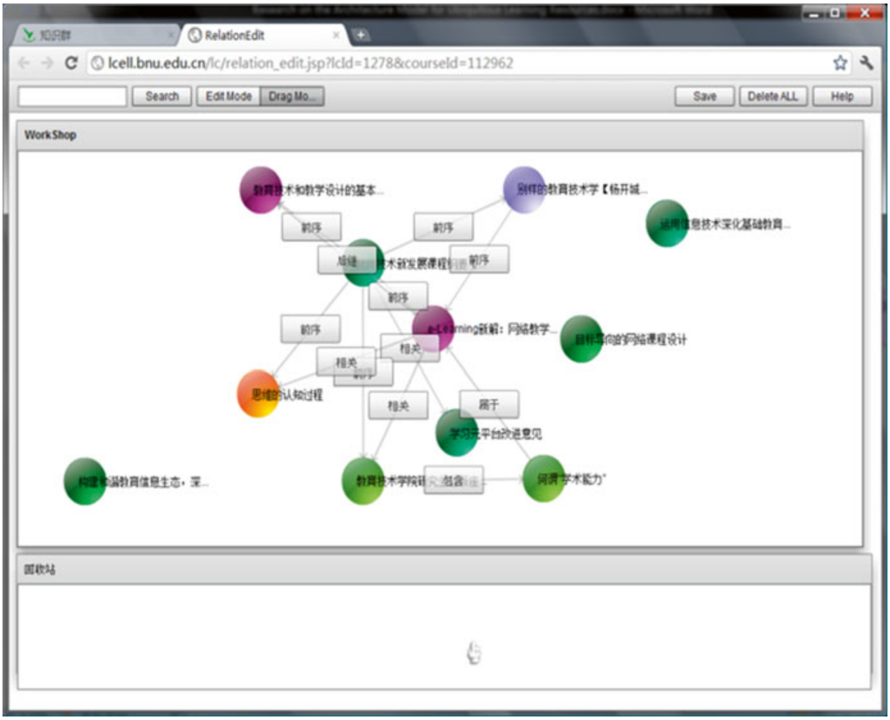

Fig. 8.3 Visualized editing of semantics network

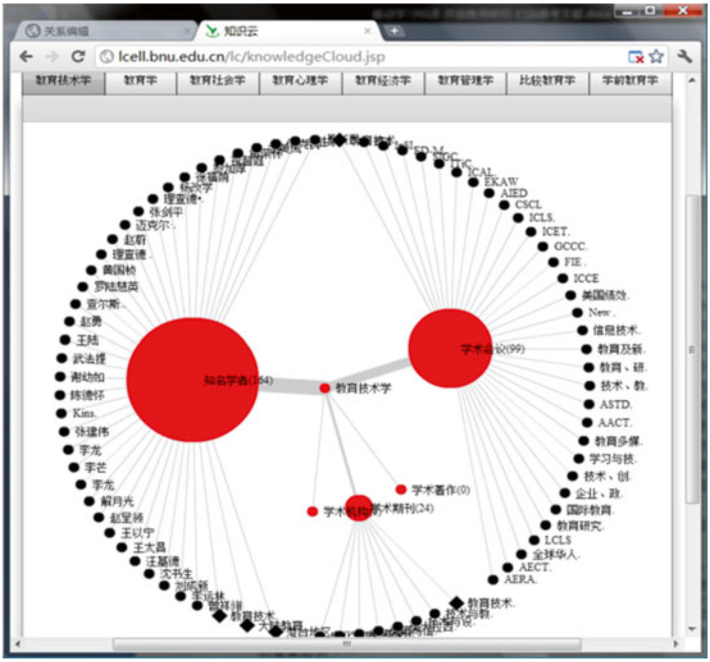

Fig. 8.4 Visualized navigation based on semantics

Semantic-based aggregation has three meanings:

(1) Learning cell could connect with other similar learning cells based on field ontology to form an extensible semantic web on certain subject over time. A learning cell could enrich its content in time by acquiring updated information from connected learning cells. (2) The learning content in learning cell is not static. It evolves during the process of application according to semantic development. According to the field knowledge ontology, learning cells can grow and divide similar to a neuron; it could search for other learning cells and resources on the same subject to form dynamic connections. (3) Learning cell grows in a structured manner. The learning content in learning cells evolves according to the structure of the field semantic ontology, which controls the development directions for learning cells, just as genes control the development of an individual.

2. Learning cell proposes a computing model for cognitive networks, which forms during the interaction with learning resources.

Traditional learning resources are limited to the sharing of physical learning resources without the consideration of people. However, learning resources in learning cells include not only physical resources but also people connected by physical resources. Constructing computing models for cognitive networks based on the interaction data of learners is important to share dynamic and social cognitive networks (Fig. 8.5).

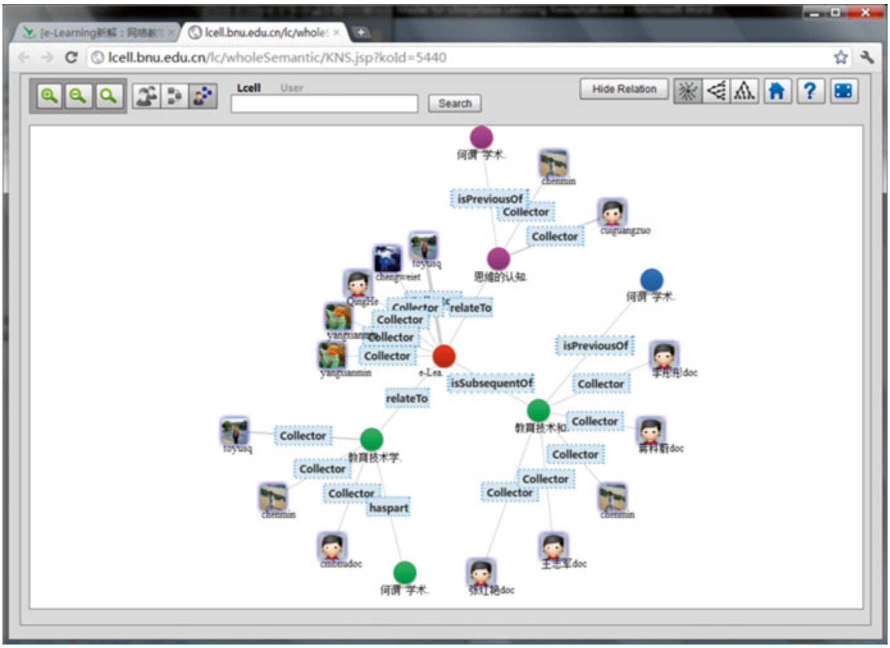

Fig. 8.5 Simulation of social cognitive network

Because learning content converges with the wisdom of all learners, the combination of physical resources and people would create a dynamically evolving and developing social cognitive network. Learners could acquire not only existing knowledge but also the learning methods and knowledge-acquiring channels. Once a network is formed between the knowledge and learners, learners would be able to continuously obtain the knowledge they need via such a network, which is characterized by the same concept as social construction and distributed context awareness.

Therefore, the social characteristics of future learning resources would gradually strengthen. In u-learning, learning resources should also serve as the bridge to connect learners in addition to being the carrier of knowledge. The cognitive network attached to learning resources is an indispensable attribute for future learning resources.

3. Learning cell provides an open and dynamic storage model for learning resources and a resource aggregation model to support context-aware learning.

The core feature of u-learning is context awareness. U-learning could provide different learning services according to different learning contexts, i.e., perceive the demands of users with intelligent learning devices and offer the most suitable learning modes and services. To realize this learning framework, we must improve the perception ability of learning terminals and redesign the aggregation model for learning resources to adapt to different contexts.

The context awareness of learning resources lies in the following two aspects: (1) intelligent adaption to learning terminals and (2) adaptability of learning content. Learners can obtain resources according to their actual needs in the most appropriate way.

The current description of learning resources is based on static-structured metadata, which cannot provide rich descriptions for different disciplines and application scenarios. This type of description and organization mechanism cannot meet the needs of context-aware and individualized u-learning. To ensure that learning content is dynamically aggregated and self-adapted, the static structure model must be changed such that each part of the learning content is organized in a process-oriented logical structure and dynamically generated.

Learning cell adopts the cold storage model of u-learning. The structure of learning content and the learning content itself are separated in distribution as illustrated in Fig. 8.6. Learning cell consists of dynamically structured resources composed of metadata, ontology, content, activity, evaluation, generative information, and multi-format data. These components connect with “education cloud services” via numerous service interfaces (such as learning activities and evaluations). “Education Cloud Services” contain an immense amount of learning resources and various related records, including activity records, editing records, evaluation records, use records, learning communities, and other information generated during learning processes.

The structure of learning content is learning process oriented, which describes objectives, conditions, and the process of learning as well as the requirements of learning content. The learning content itself can be stored in resource servers all over the world.

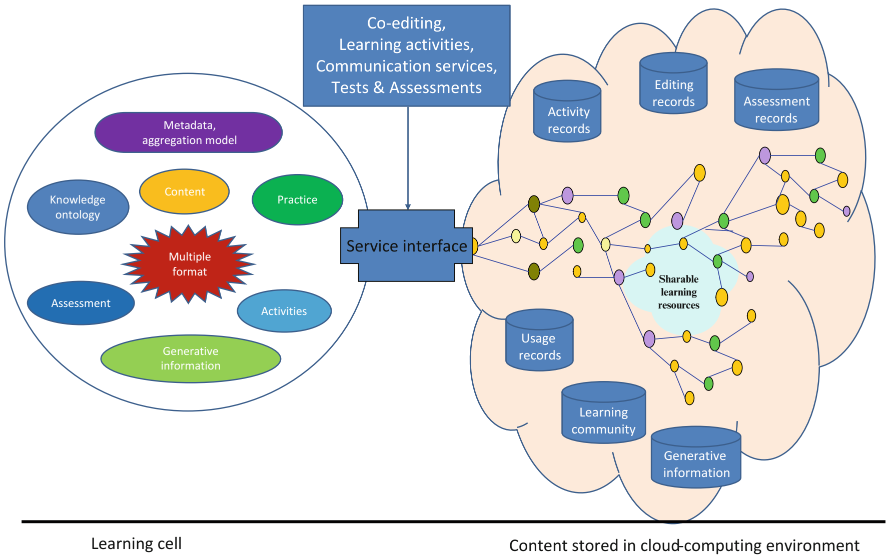

Fig. 8.6 Cloud storage model of learning cell

These resources are developed, shared, and stored in different nodes. Different resources connect to each other via dynamic semantics. When learners enter u-learning environments, they access the dynamic structure of learning content. The education cloud service system would search for the appropriate content to fill that structure according to context parameters. The structure of the same learning content generated by the system depends on the learner. When learning cells are accessed in different contexts, the aggregated learning content is different to meet individualized needs of different learners.

Learning Cell Runtime Environment

The success of learning object relies on a SCORM-supported learning management system and an IMS-LD-supported learning platform. Learning cell operates independent of a specific supporting environment. The architecture of the learning cell runtime environment is shown in Fig. 8.7. Key components include the message transfer controller, resource locator, repository, learning cell runtime engine, active adaptor, and learning service interface.

The *message transfer controller* receives user request information from the U-network, analyzes the information, and decides where to send the information.

The *resource locator* manages resource indices, searches learning resources at the requests of users, and locates the resources in the repository.

The *repository* stores learning cells and other resources, including generative information, semantic relationships, user information, and information about various devices.

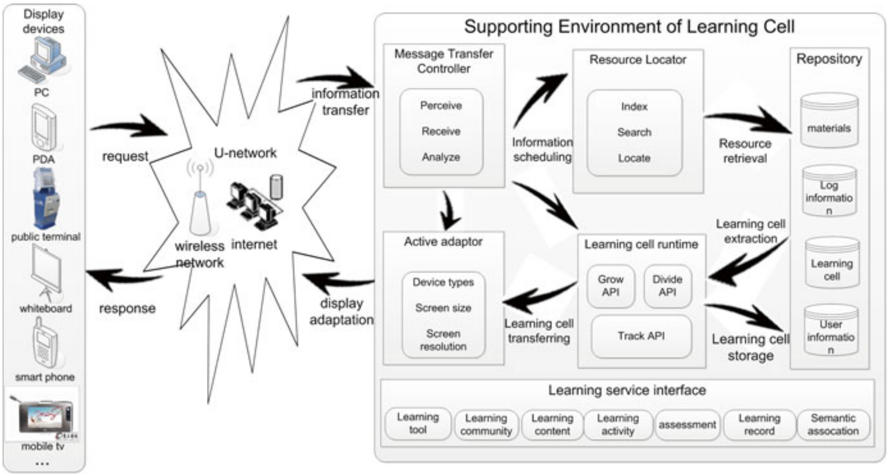

Fig. 8.7 Architecture of the learning cell runtime environment

The *learning cell runtime engine* manages the information exchange between learning cells and the external environment; it consists of a series of APIs, including the learning cell grow API, the learning cell divide API, and the learning cell track API. Via this engine, the content of learning cells can evolve, resources can be aggregated based on semantics, and the learning cells themselves can divide and grow.

The *active adaptor* receives device information from the message transfer controller; analyzes device types, screen sizes, and screen resolutions; and transforms the content into the most appropriate format for display on devices.

The *learning service interface* provides users a series of learning services, including learning tools, learning communities, learning content, learning activities, learning assessments, learning records, and semantic associations. Learners can use these interfaces in the U-network and access learning support services from any location and at any time.

A U-network is a ubiquitous network that supports u-learning; it is accessible via the Internet, wireless communications, and digital TV networks, to which users can easily connect with a device. A U-network manages the data transfer and device communication that are necessary to transfer content among learning cells. Various display devices, the U-network, and the learning cell runtime environment work collaboratively to form a learning cell-based, seamless learning environment.

The learning cell runtime environment is based on J2EE and SOA and can be divided into four layers: the repository layer, the service layer, the application layer, and the display layer.

The *repository layer* stores various data from the runtime environment and includes (1) a resource repository, which stores all of the resources, including learning cells and knowledge groups; (2) an ontology repository, which stores all of the knowledge ontology in the environment, including predefined ontology and user-generated ontology; (3) a user information repository, which stores information such as user portfolios and trust degrees; (4) an activity repository, which stores information such as discussions, voting patterns, and reflections; (5) a tool repository; and (6) a log repository, which stores logs from learning cells, knowledge groups, learning activities, and user operations.

The *service layer* provides various services based on data from the repository layer, including learning activities, learning assessments, learning tools, version controlling, ontology editing, resource management, resource aggregation, resource indexing, format matching, and learning activities.

The *application layer* provides applications to users by calling services from the service layer. The applications include learning cells, knowledge groups, knowledge clouds, learning tools, personal space, and learning communities, all of which offer varied learning experiences.

The *display layer* automatically converts the format of learning cells according to the information provided by the display devices, which could include digital TVs, computers, smart phones, public information terminals, and live telecasts, so that learning cells can be properly displayed on different devices.

Learning Cell System Development

Researchers have developed several types of ubiquitous learning systems. Ogata et al. (2008) developed the basic support for ubiquitous learning (BSUL) system to support classroom teaching and learning. Hwang et al. (2009) developed a context-aware u-learning system to guide inexperienced researchers to practice single-crystal X-ray diffraction operations and proved its systematic nature, authenticity, and economy. Liu et al. (2009) developed an environment of ubiquitous learning with educational resources (EULER) based on radio-frequency identification (RFID), augmented reality (AR), the Internet, ubiquitous computing, embedded systems, and database technologies to learn outdoor natural science. Huang et al. (2012) developed a ubiquitous English vocabulary learning (UEVL) system to assist students in carrying out a systematic vocabulary learning process in which ubiquitous technology is used to develop the system and video clips are used as the material.

However, all of the above u-learning systems were not meant for addressing the need of designing special learning resources for u-learning. They adopt traditional learning resources, such as learning object, CAI courseware, video, test, etc., which cannot meet the demands of u-learning development (Yang et al. 2013). The learning cell system (LCS) is an open learning platform developed for u-learning based on the concept of learning cell. It supports collaborative knowledge editing, knowledge aggregation, and evolution, multiple-level interaction, and multidimensional communication. Specifically, LCS allows the orderly evolution of resources, facilitates shared cognition networks and the collaborative construction of ontologies, and provides open service tools. LCS can be accessed at http://lcell.bnu.edu.cn. Since it was inaugurated in May 2011, 10747 users have registered, 57705 learning cells have been created, 66 learning applets have been generated, 3,425 knowledge groups have been formed, and 83 learning communities have been formed (as of Nov 15, 2013) (Fig. 8.8).

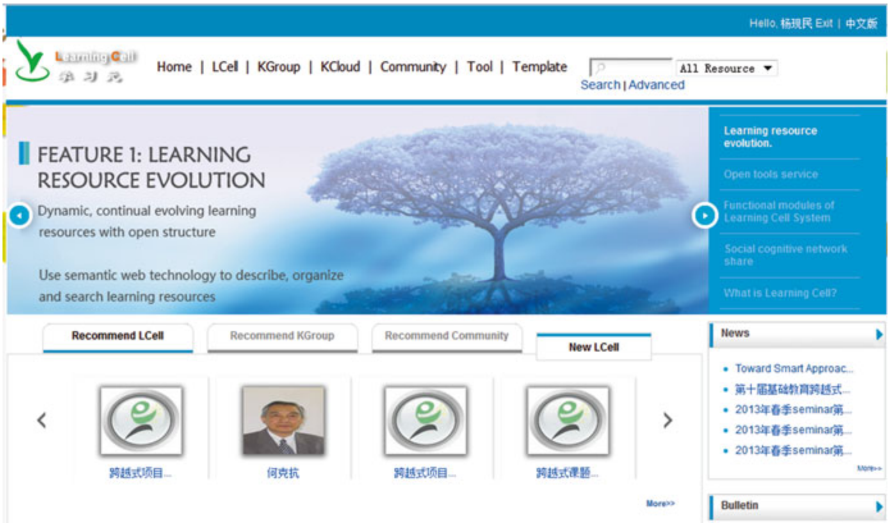

Fig. 8.8 Screenshot of the LCS home page

Functional Framework of LCS

The functional model of the LCS is shown in Fig. 8.9. Its main functions are knowledge group (KG), knowledge cloud (KC), learning cell (LC), learning tool (LT), personal space (PS), and learning community (LCM).

The LC function assembles all of the learning cells in the environment. Each learning cell is a resource entity, which can be a lesson or a knowledge point. A learning cell contains not only learning content but also learning activities, KNSs, semantic information, generative information, and multi-format data. A learning cell can also be an independent learning resource used by learning communities. Different learning cells on a related subject can be gathered into a knowledge group. Learning cells can introduce related assistant learning tools to support u-learning. Learning cells are available in multiple formats, such as web pages, e-books, concept graphs, and 3D models (Fig. 8.10).

To control the quality of learning resources, LCS provides a scoring function that allows anyone to comment and score any learning cells. Those learning cells with lower scores that have remained unimproved for a long time (over than 2 month) will automatically be removed from LCS. Furthermore, a two-way interactive feedback model (TIFM) (Yang et al. 2014), which is a kind of trust evaluation model, was also adopted in the LCS to judge resources and the credibility of users. Additionally, an incentive mechanism, including the rank of title, virtual and real awards, and rank of contribution degree, is implemented in the LCS to attract more users to engage in knowledge creation and sharing.

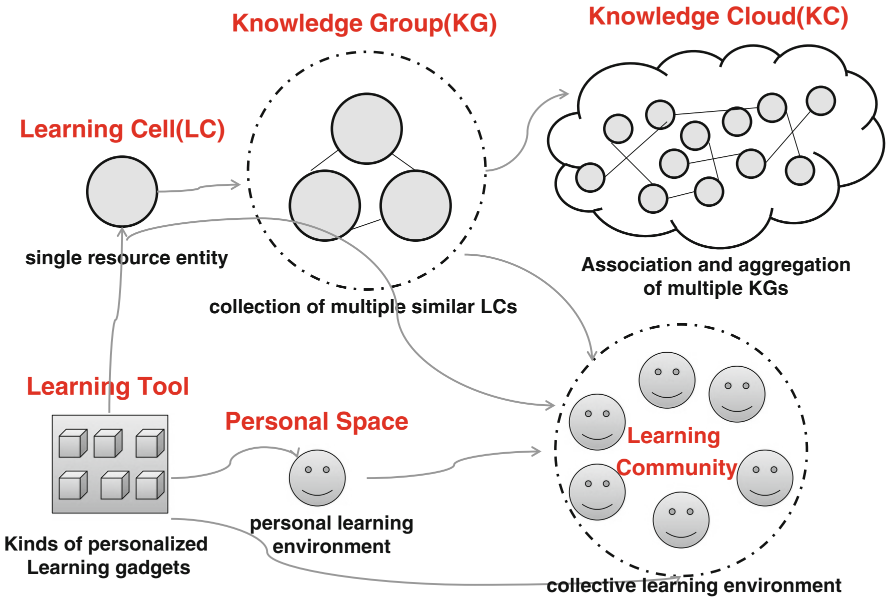

Fig. 8.9 Functional model of the application layer of the learning cell runtime environment

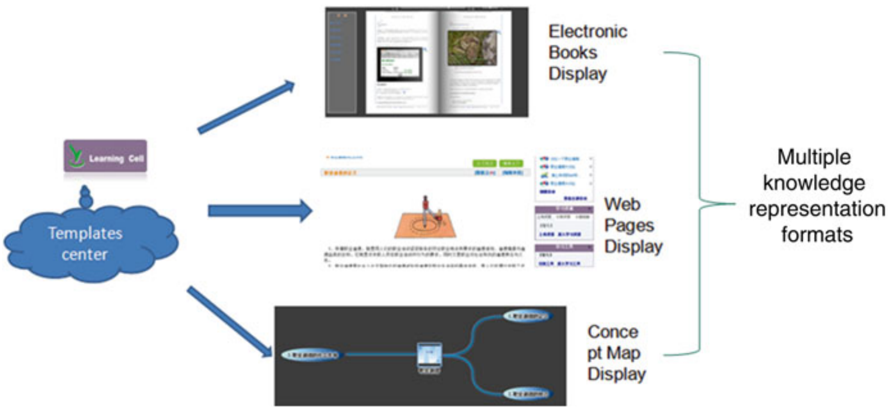

Fig. 8.10 Multiple formats of learning cells

The KG function assembles all of the knowledge groups in the environment. Each knowledge group consists of learning cells on related subjects. For example, a course can be a knowledge group, and each lesson or knowledge point in the course can be a learning cell. When users access the knowledge group, they can find all of the learning cells related to the course.

The KC function aggregates multiple knowledge groups. Different knowledge groups are connected via semantic relationships. In a knowledge cloud, users can easily find all of the knowledge groups related to their subject.

The LT function assembles all of the personalized learning gadgets. In LT, users can preview or save gadgets as well as upload gadgets. All gadgets conforming to Open Social standards can be integrated into LT. These gadgets can be used by learning cells, knowledge groups, personal spaces, and learning communities. For example, some gadgets, such as translating gadgets, can be integrated into the learning content during the content creation or editing process to enhance the learning efficiency.

The LCM function assembles all of the learning communities in the environment. A learning cell is a collective learning environment (CLE) in which community members communicate, collaborate, or share with each other. Community members can publish a notice, initiate a discussion, share interesting resources, and initiate learning activities. Learning communities are related to LC, KG, and LT, and related learning cells, knowledge groups, and knowledge tools can be introduced into learning communities. In addition to learning communities, all users have their own personalized learning environment.

PS is the personal learning environment (PLE) of each user, which contains functions for personal resource management, friend management, schedule management, gadget management, and personalized learning recommendations. In personal space, users can post basic personal information, manage (create, collaborate, and subscribe) interesting learning cells and knowledge groups, and select recommended learning resources.

Features of LCS

Compared with the general online learning system, LCS has six features, as follows:

1. LCS uses ontology technology based on the semantic web to organize various learning resources in the platform. In addition to using the static metadata defined in the IEEE LOM specification, such as title, language, description, keywords, and so forth, LCS also uses an extensible subject knowledge ontology model to represent the intrinsic logic relation between different learning cells.
2. Learning resources in LCS are not fixed, but open toward continual generation and evolution. LCS allows users to collaboratively edit learning content, using the wisdom of the crowd to promote the growth of the learning resources.
3. LCS has an android client developed based on the above model of resources by Gao and colleagues (2012). This mobile app can run on smartphones, tablets, and other mobile devices.
4. Learning resources in LCS involve learning content, activities, as well as social cognitive networks formed through learner interaction with these resources. Beyond general social networks interconnecting people, the social cognitive network shows people-knowledge connections constructed in the process of interaction that is essential to the work of learning communities.

5. LCS captures dynamic semantic relationships among the learning resources. Such relationships are established in an automatic way based on standardized semantic relationship between the resources; they are further updated and developed as the users make change to the resource content, description information, etc.
6. LCS records process information about learners' learning based on five categories: learning attitude, learning activities, content interaction, resources and tools used, evaluation, and feedback. According to different learners' different learning goals, evaluators (generally evaluator is the resource creator, as teacher's role) select the appropriate information and set several personalized evaluation schemes in advance.

Application Scenario Analysis

LCS provides technological support for u-learning. It has been particularly tested to support the following five types of usages:

1. Resource co-construction and sharing

LCS supports the co-construction and sharing of resources in line with the Web 2.0 concept. Any registered user can participate in the co-creation of resources. In schools, teachers and students can create online courses together. With additions and changes of learning resources and information automatically saved, LCS will generate standard courses in conformity with the SCORM standard. Teachers can also collaborate to build the school-base resource center, co-designing teaching plans to address a focal curriculum topic, co-accumulating teaching materials, and integrating these into a whole teaching plan. In corporate training contexts, the human resources department can use LCS to capitalize on the collective wisdom of the staff, to encourage employees to participate in the development of training resources, to realize "training by doing" and "learning by doing," with the collective input of the staffs contributing to building useful training resources for their enterprise.

2. Knowledge management

LCS can also be used to achieve personal and organizational knowledge management. Users can construct their personal knowledge base in LCS, upload their own knowledge resources into a personal knowledge space for centralized management and maintenance. Meanwhile they can share knowledge with friends and engage in ongoing dialogues and interactions. Through this process of participation and interaction, they will establish and perfect personal knowledge networks and social networks. The organization can create different knowledge groups and encourage members to create LCs based on their valuable experience of problem solving and share them within the organization to promote the transformation of tacit knowledge and explicit knowledge and, eventually, to improve the overall organization performance. As an example of using LCS for knowledge management, our "Kuayueshi" (basic education research project) project team and LC project team at Beijing Normal University are using LCS to do project-based knowledge management.

3. Organizational learning

In addition to its rich resources, LCS also provides a library of learning activities and tools. In LCS, organization can attract members to actively participate in learning by designing rich activities and tap into one another's wisdom to promote networking, collaboration, and communication. In addition, members also can upload and share tools closely related to organizational learning and work. When organization members have a problem, they can solve problems through timely communication with the help of special learning tools. The learning activities module in LCS has the function of the online assessment. Teachers can create test questions and design assessments; students can understand gaps in their own knowledge structure by self-testing. Enterprise training department can use the online assessment function to evaluate employees' knowledge and promote the staff's online learning.

4. Regional network-based teaching study

Regional network-based study is an important way to improve teaching quality and promote teachers' professional development. Teachers can share teaching experience with each other through LCS. Research staffs can set research topics and invite teachers of related subjects as collaborators in order to seek breakthroughs of teaching through collective power. They can also build different learning communities for different subjects, encourage the same subject teachers sharing teaching resources, and exchange knowledge and experience online. There are currently ten schools with more than fifty primary school teachers involved in the "Kuayueshi" project (basic education research project) who are using LCS to do regional network-based study in Anhui province of China.

5. College-level online education

Different from the traditional LMS, such as BB, Moodle, Sakai, 4A, etc., LCS has more Web2.0 features besides resource management, discussing and communication, activity design, and other teaching support functions, with more focuses on the construction of knowledge networks and social networks. These features can support online teaching in higher education. Currently, young instructors from the Faculty of Education at Beijing Normal University have started to deploy LCS to conduct network teaching, including the undergraduate course "The design and development of multimedia and network teaching resources" and the doctoral program "The new development of education technology."

Conclusion

Existing schemes focus on learning resource sharing in closed environments. They ignore the sustainable development and evolution of learning resources, the dynamic and generative connections between learning resources, and the dynamic learner-teacher relationship built upon learning resources. The proposed learning cell extends beyond learning objects. It is characterized by an evolving development, cognitive network connections, semantic-based aggregation, self-tracing nature, and micromation features. Learning cell could better support the needs of ubiquitous learning and collective construction to share learning resources. Learning cell is designed to enable future seamless learning space supported by pervasive computing technology, and it will be the keystone in the realization of u-learning.

Our research team has successfully developed a prototype system, learning cell system, and implemented the basic ideas of learning cell. A usability testing was conducted using an SUS tool developed by John Brooke (Brooke 1996). The questionnaires were published using a professional investigation platform (http://www.sojump.com/). Among the 50 users participating in this testing, 68 % felt confident using LCS, 26 % felt neutral, and 6 % felt unconfident and were not willing to use the system. Generally speaking, most users had positive attitudes toward LCS. Further investigations indicated that unconfident users felt that LCS was too complicated. In the future, we will simplify LCS operations and further investigate LCS applications.

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