FROM LEARNING OBJECT TO LEARNING CELL: A RESOURCE ORGANIZATION MODEL FOR UBIQUITOUS LEARNING

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ABSTRACT

The key to implementing ubiquitous learning is the construction and organization of learning resources. While current research on ubiquitous learning has primarily focused on concept models, supportive environments and small-scale empirical research, exploring ways to organize learning resources to make them available anywhere on-demand is also crucial. This paper presents a new organizational model for organizing learning resources: Learning Cell. This model is open, evolving, cohesive, social and context-aware. By introducing a time dimension into the organization of learning resources, Learning Cell supports the dynamic evolution of learning resources while they are being used. In addition, by introducing a semantic gene (knowledge ontology) into the model, Learning Cell can describe the internal structure and external relations of learning resources more flexibly, allowing the evolution of learning resources to be controlled in an orderly way. Furthermore, by employing a computational model of a social cognition network, Learning Cell enables not only materialized resource sharing but also the sharing of social cognition networks. Finally, by separately deploying resource structures and resource content in the cloud storage model, Learning Cell achieves context awareness of u-Learning resources. Learning Cell represents a resource aggregation model that is different from the learning object model. It makes up for the defects of existing learning technologies in the following areas: the sharing of process information and social cognition networks, the intelligence of resources, and the evolution of content. Learning Cell provides a theoretical framework for and practically explores the possibilities of u-Learning resource organization.

KEYWORDS

Ubiquitous learning; learning object; learning resource; resource organization model

1. INTRODUCTION

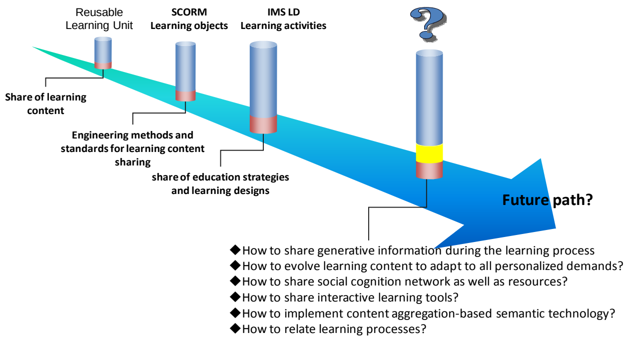

Figure 1. The development of learning resource sharing

Three generations of resource organization models have shaped the field of e-Learning: Integrable-ware (Reusable Learning Unit), Learning Object and Learning Activity. Figure 1 shows the development of learning resource sharing. The Integrable-ware model (Li, 1997) initiated resource-sharing research; it emphasizes the combination and reuse of small-sized learning resource units. The Learning Object model (ADL, 2004) provides solutions for data exchange between different Learning Management Systems (LMS), allowing structured and interactive learning objects to be shared between LMS. The Learning Activity model (Britain, 2004) supports high-level sharing of learning processes and activities by reusing learning methods, learning strategies and learning activities. The emergence of IMS-LD (IMS GLC, 2003) extended the sharing of learning resources from learning objects to learning activities, signaling a shift in learning resource sharing from a technological problem to an education problem.

However, the sharing of learning activity designs is not the ultimate goal of learning resource sharing. New learning technologies aim to cater to ubiquitous learning.

2. RELATED WORKS

Existing learning resource standards, such as IEEE LOM, SCORM, etc., focus on describing and packaging resources, and their primary goal is to enable resource sharing and reuse across different platforms. Undeniably, these resource technologies play important roles in promoting learning resource transmission and sharing, but they only support one-way information transmission (experts generate resources while users consume them). Such models ignore the valuable information generated by learners during the learning process, making the update cycle too long and unsuitable for users. Existing resource standards that are designed for traditional e-Learning are characterized by knowledge transfer tools and are, not suitable for new learning modes like collaborative learning and discovery learning, where resources can be collaboratively developed and shared using social networks.

Because the existing learning resource sharing standards do not conform to the development of learning technologies, some international research groups have initiated work on the next-generation model for sharing learning resources. For instance, the Instructional Management System Global Learning Consortium (IMS) has published the Common Cartridge V1.0 standard (ADL, 2008). In addition, Advanced Distributed Learning (ADL) is working on a standard called SCORM (Sharable Content Object Reference Model) version 2.0 (Allen, 2008). Although in development, these standards in some ways reflect the defects of existing sharing models, and reflect the demands of researchers and practitioners for next-generation sharing models.

SCORM 2.0 and IMS Common Cartridge show that international standardization groups have made significant contributions for the development of learning technologies. However, they are not suitable for application in u-Learning for the following reasons:

(1) Both of these projects allow the integration of resources of a variety of sources and types but fail to plan and design tools that would enable the renewability of these resources. To date, Web 2.0 communities such as Wikis, interactive Q&As and professional BBSs, which users actively participate in to construct content, are common tools used by many learners to search for information, seek help and troubleshoot. Therefore, the goal of research aimed at learning resource development is to structurally support the assimilation of collaboratively created/edited learning resource content, to promote its evolution and development and to completely preserve and share the record of resource evolution and knowledge construction.

(2) They ignore human factors in resource organization. Learning Object models only consider file organization and packaging, it has no human factors. Learning design goes a step further by enlarging the sharing scope to the design ideas of teachers and allowing learners to participate in pre-defined learning activities. However, it does not support relationship construction between learners. Based on cognitive learning theory, a P2C (People to Content) learning mode cannot reflect the essence of e-Learning because learning essentially consists of interactions between people, and the most valuable e-Learning mode should be P2P (People to People).

(3) They are unable to meet informal learners' needs for individualized and diversified learning. The intelligence characteristics of these learning resources are insufficient to provide the personalized and diversified learning demanded by informal learners. Most of the current learning resource standards are static metadata schemes that ensure shared cross-platform characteristics but sacrifice flexibility. These schemes hardly meet the expansion needs arising from the varied application scenarios. The semantic tagging and modeling of learning resources would provide the data foundation for adaptive learning (Jovanović et al., 2007; Bouzeghoub et al., 2006; Nilsson, Palmér, & Naeve, 2002). Some researchers have tried to use ontology technology to build models of digital courses, yet these studies are limited to curriculum in specific disciplines. There are few general descriptive models and application tools (including modeling tools, retrieval tools, reasoning tools, etc.) that can be adapted to a variety of subjects. Ubiquitous learning requires intelligent, situational and adaptable resources. A resource organization model designed for a ubiquitous learning environment must take this into consideration.

(4) SCORM, IMS learning design standards and Common Cartridge norms are all structurally appropriate for creating complete course and teaching units and emphasize one-way designs in which developers and teachers organize and transfer learning content and activities. This is appropriate for formal learning styles that involve teacher participation. This limited sharing range and prevents resources from being imported and exported between different LMS. The models in question allow for neither a wide range of resource sharing across organizations nor the miniaturization of sharing grain size and thus do not meet the requirements of informal learning, i.e., short time, miniature study particle size. It also limits the scope of sharable learning resources to learning content and instructional design and does not allow the information generated in the learning process to be shared. Generative information produced during the learning process is an appropriate object for observation that can promote learners' learning.

Based on the above problems, this study attempts to go beyond Learning Object and proposes a new sharable learning resource model for u-Learning. The innovative features of the model include its context-awareness, evolutionary development, cognitive network connectivity and semantic-based aggregation. We also present the runtime environment design and implementation of the model.

3. THE PROPOSED MODEL: LEARNING CELL

Because they are based on centralized storage and hierarchical directory structures, existing learning resource organizations cannot meet the demands of u-Learning. In this paper, we propose a new learning resource describing and packaging scheme called Learning Cell, which is evolving, open, intelligent, cognition-connected and semantic-aggregated (Yu, Yang, & Cheng, 2009).

3.1 Principles of Learning Cell

To accommodate u-Learning, Learning Cell is based on Connectivism and collaborative knowledge construction theories and features cloud storage, a dynamic structure and non-static data elements. As a digital learning resource, Learning Cell is generative, open, self-evolutionary, connective, social, micromatic and intelligent. The meaning of "cell" is multifold:

Component: It reflects the characteristics of standardization, micromation, reusability and integrability that define Learning Cell. From this perspective, the design concepts of Learning Cell and learning object models are similar.

Original: Learning Cell develops from non-existent to existent, from small to large, from large to strong and finally to long-lasting. Learning Cell changes during the usage process rather than remaining static. The evolving and germinating characteristics of Learning Cell distinguish it from learning object models.

Neuron-like: Learning Cell is able to perceive environments, adapt to terminals and generate rich connections. The connections among Learning Cells and humans form social cognitive networks. When those networks grow to a certain scale, Learning Cell would gain social intelligence, which is also an essential distinction between Learning Cell and learning object models.

From the above descriptions, we can see that Learning Cell is a learning resource that is open, generative, evolvable, connected, cohesive, intelligent, adaptive and social. It is developed from the Learning Object model and designed for u-Learning. The basic idea is to introduce a time dimension and an interpersonal cognition network into learning resources to make the learning resource evolvable. During evolution process, generative information and the revision history are recorded, an interpersonal network is generated and human and knowledge connect with each other to form a knowledge network, which allows students to construct knowledge, understand the context of that knowledge and share collective wisdom through social cognition networks.

3.2 Structural Model of Learning Cell

Learning Cell uses the cloud storage model to support u-Learning resources. The structure of learning content and the learning content itself are separated in distribution, as Figure 2 illustrates. Learning Cell is composed of dynamically structured resources: metadata, ontology, content, activities, assessments, generative information and multi-formats. All of these components connect with the "Education Cloud Services" through a variety of service interfaces (e.g., learning activities and assessments). In "Education Cloud Services", there are 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.

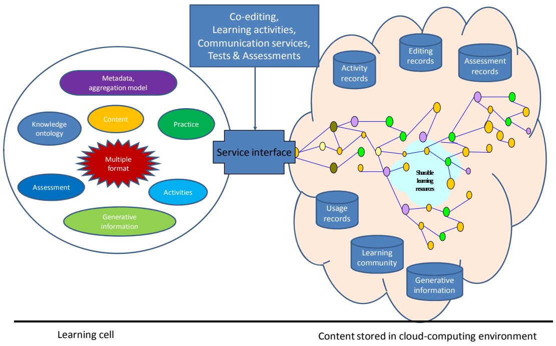

Figure 2. The Cloud Storage Model for ubiquitous learning resources

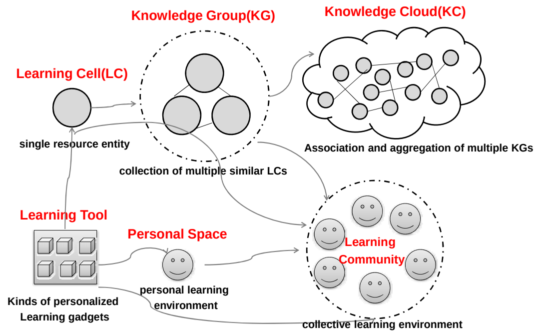

Figure 3. Functional model of the Application Layer of the Learning Cell runtime environment

Learning Cell is a learning service that can be accessed through a URL, which allows it to provide users with context-appropriate learning content and applications. Learning Cells are learning goal oriented and can exist independently or be connected into a personalized knowledge network. The network contains metadata, aggregation models, knowledge ontology, learning content, learning assessments, learning activities, generative information, learning service interfaces and other resources.

Metadata is used to describe the attributes of Learning Cells so that they can be easily categorized, indexed and shared.

Aggregation models prescribe the inner components and connection modes of Learning Cell. In contrast with Learning Object, Learning Cell adopts a semantic-based network aggregation model in which different components dynamically connect with Learning Cell to form a network. Different learning resources can be aggregated into a Learning Cell, and different Learning Cells can be aggregated into larger-scaled knowledge groups or knowledge clouds.

Knowledge ontology describes the basic concepts and inter-concept relationships of related knowledge, which are used to construct effective aggregation models and promote the aggregation of Learning Cell components and the dynamic connection of Learning Cells containing similar content.

Content is the main component of a Learning Cell. Learners use content to obtain learning resources, codify knowledge and reconstruct long-term memory cognition. Content needs to have specific subjects and goals and to be independent and complete, even with small granularity.

Assessment is used to examine how learners grasp learned knowledge and to adjust learning strategies according to the assessment results. Learning Cell records all of a learner's interactive information and forms assessment reports after performing information analyses.

Activities promote deep interactions between learners and content; they are process oriented and enable the sharing of learning processes, strategies and activities.

Generative information is generated during the process of using Learning Cell; it contains user information, interaction information, Learning Cell revision history and so on.

Multiple formats indicate the different forms in which Learning Cell is available, including http format, e-book format, knowledge map format and video or audio format. These formats allow Learning Cell to be displayed on different terminals in a suitable way. Different formats are automatically transformed and stored at implementation.

Service interface is the primary channel of information exchange between Learning Cell and the cloud-computing environment. It defines the interface both to acquire and update process information when learners perform learning activities through Learning Cell and to update the inner components and structure of Learning Cell, making Learning Cell generative.

The cloud storage architecture embodies the importance of distributed computing and cloud computing to learning technologies. Future learning resources would not be simply deployed from a centralized inner server but distributed and connected around the world.

3.3 Core Features of Learning Cell

Learning Cell retains the accessibility, adaptability, affordability, durability, interoperability and reusability of Learning Object but has, in addition, the following five unique properties:

(1) **Openness:** Open learning resource provides not only open access but also open content. Unlike the traditional static and closed-resource organization model, Learning Cell is open and based on a dynamic resource structure. Learning Cell allows resources to be updated with to usage information, to grow by absorbing valuable online content such as Gadget, to interact with the external learning environment and to be integrated with learning activity designs. Each Learning Cell is equipped with a learning system service interface, allowing the learning process to be traced and information to be exchanged between Learning Cell and the runtime environment. Unlike RTE in the SCORM model, the service interface of Learning Cell can be used not only by its host server but also by distant systems through API, which facilitates activity sharing and the creation of an education cloud for dynamic content.

(2) **Evolvable:** Traditional learning content is static and difficult to update. SCORM course packages can split and recombine content but do not support content revision. Learning Cell makes learning content evolvable because it updates content according to the feedback it receives during the learning process. Based on the idea of Web 2.0, learning content is no longer generated by a few professionals but is generated and updated by public users and connected via a network. Unlike Learning Object, Learning Cell saves not only predefined course content, exercises and activities but also information generated during the learning process, such as submitted work, annotations on learning content and learning records. Revisions to learning content are also recorded to reflect the evolving process of learners and Learning Cells. By recording this generative information, Learning Cell can satisfy the various dynamic and personalized demands of learners by adjusting content and the content's structure, adapting it to the changing learning environment.

(3) **Cohesive:** Learning Cell is cohesive, organizing all elements of the learning process into an orderly whole. The "gene" of a Learning Cell is formed according to an ontology-based knowledge structure and aggregation model, which controls the evolution and development of each Learning Cell.The most important distinction between Learning Cell and Learning Object or SCORM-based online courses is the application of semantic network and ontology technology, which makes Learning Cell resemble an organism; it grows and evolves under the control of an internal "gene". Except when it exists as an independent and complete learning unit, each Learning Cell could serve as a node in resource networks and could connect with other nodes according to certain rules. Learning Cell supports the semantic-based network aggregation model, which is different from the hierarchical aggregation model. It can not only aggregate different learning materials into Learning Cells but also aggregate different Learning Cells into even bigger Knowledge Groups or Knowledge Clouds.

(4) **Social:** Because learning content is infused 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 learning methods and knowledge acquisition channels. Learning Cells include not only materialized learning resources but also interpersonal networks generated during the evolution process. Learning Cells can be regarded as intermediaries between learning channels and social wisdom. On one hand, Learning Cells record and trace the learner information related to a learning resource, generating learner group space about the resource; on the other hand, Learning Cells automatically connect to similar Learning Cells, combining each other's learner group space and thereby achieving high-level sharing of the whole learning network system. Learning Cells connect humans through learning content and generate a social cognition network in ubiquitous learning space

(5) **Context Aware:** The core feature of u-Learning is its context awareness. It can adapt the learning services to the learning contexts; in other words, it can perceive users' demands using intelligent learning devices and offer the most suitable learning modes and services. To realize such a learning model, we must improve the perception ability of learning terminals and re-design the aggregation model to allow 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. When learners can obtain resources according to their actual needs in the most appropriate way, they are learning in context.

4. IMPLEMENTATION OF LEARNING CELL

Learning Cell operates independent of a specific supporting environment—Learning Cell System (LCS). The functional model of LCS is shown in Figure 3. 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; it 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. 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

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 not only preview or save gadgets but also 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 space, and learning communities. For example, to enhance learning efficiency, some gadgets, such as translating gadgets, can be integrated into the learning content during the content creation or editing process.

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, containing 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 to) interesting learning cells and knowledge groups, and select recommended learning resources.

5. PRACTICAL APPLICATIONS AND EVALUATION

Learning Cell System (LCS) is an open knowledge community developed for u-Learning. It supports collaborative knowledge editing, knowledge aggregation and evolution, multiple-level interaction and multi-dimensional 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, 7579 users have registered, 12068 Learning Cells have been created, 80 learning applets have been generated, 1230 knowledge groups have been formed, and 84 learning communities have been formed (as of Jan. 25, 2013).

5.1 Practical Applications

We carried out two practical applications of LCS. The first application was designed to support e-Learning for graduate students and the second to support regional collaborative teaching research for primary and secondary school teachers.

In the e-Learning use case, a course was given to 25 graduate students through LCS, and the process is shown in figure 4. The learning is based on course knowledge construction and social cognition network sharing, integrated with collaborative resource creation, learning activities, personalized assessments, on-line communities and mini-annotations.

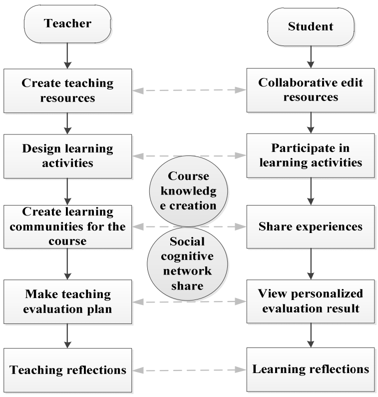

Figure 4. E-Learning process based on LCS

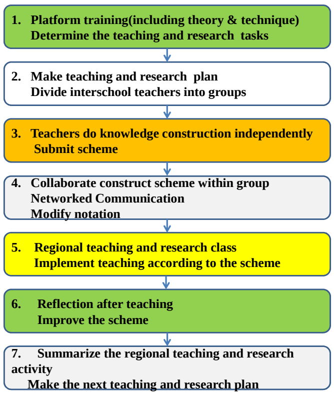

Figure 5. Regional collaborative teaching research process based on LCS

In the regional collaborative teaching research use case, teachers can share experience with each other through LCS. The director can set several knowledge groups on the focused subjects, and invite related teachers to collaborate on the research. Meanwhile, learning communities can be set up to encourage teachers to share their resources, knowledge and experience. The application was performed in Feixi County, Anhui Province, with 50 participating teachers in 10 schools. The collaboration process is shown in figure 5.

5.2 Evaluation

In the above two case studies, investigations were carried out to determine the LCS's usability and user attitudes.

The usability investigation was based on an SUS tool developed by John Brooke (Brooke, 1996), and the questionnaires were published using a professional investigation platform (http://www.sojump.com/). Fifty users participated in the investigation. The result shows that 68% of users felt confident using LCS, 26% of users felt neutral, and 6% of users 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.

User attitude investigations was carried out on the teachers involved in the collaborative research case study. Twenty-five questionnaires were sent out by email and 23 (92%) were returned. The result shows that 82.61% of teachers liked LCS-supported collaborative research, and 8.7% of teachers disliked it. Further investigations indicated that some teachers felt LCS was too complicated to use without additional usage guidance.

The above investigations reveal that most users feel that LCS is acceptable but believe that some problems still exist. In the future, we will simplify LCS operations and perform more and deeper investigations on LCS application.

6. CONCLUSION

The organization of learning resources is a fundamental factor of seamless learning environments. Based on Learning Object, this paper proposes a new learning resource organization model, Learning Cell, which provides a theoretical and practical basis for resource organization in future u-Learning.

To highlight the features of Learning Cell, comparisons of Learning Cell and Learning Object are made in Table 1.

Table 1. Comparisons of Learning Cell and Learning Object

	Learning Object	Learning Cell
Background	To resolve the problems with disorder, isolation, sharing and low retrieval efficiency associated with e-Learning resources; introduces the idea of object-oriented computing	With the emergence of semantic webs, cloud computing, ubiquitous computing, the paradigm of e-Learning needs to change
Concept and Features	Re-usable, accessible, affordable, durable, and interoperable	Generative, open, connective, social, evolutionary in development, cohesive, intelligent, and miniaturizable
Underlying Theory	Behaviorism and cognitive learning theories	Social constructivism and situational cognitive theories
InformationOrganization	Other-organized; one-way transmission of information	Self-organized; two-way transmission of information
Information Model	Learning content focused	Learning content in combination with learning activities, generative information, KNS and semantic ontology
Repository structure	Centralized repository	Cloud storage model
Quality Control	Rely on experts	Based on social trust and knowledge ontology mechanisms
Sharing Scope	Low-level content sharing	High-level intelligence sharing, including learning activities, learning tools, interpersonal relationships and generative information

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