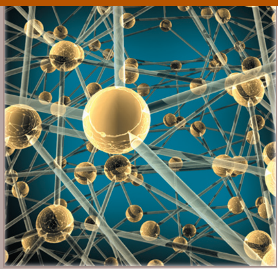

Personalized Service-Oriented E-Learning Environments

The social component of Web 2.0-related services offers users many opportunities for interface personalization. Learning environments offer an ideal case study because they require customization and must adapt to life-long learning needs in a rapidly changing environment. Consequently, researchers are already starting to define the latest wave of next-generation e-learning systems. The authors analyze current trends in e-learning architecture evolution and identify merits and limitations. They also describe a new architecture that captures the needs of both formal (instructor-led) and informal (student-led) learning environments.

Mario Muñoz-Organero, Pedro J. Muñoz-Merino, and Carlos Delgado Kloos
Carlos III University of Madrid

The first steps in defining and providing e-learning platforms in the early 1990s were based on distributing instructor-provided knowledge via a central learning-management system (LMS), sometimes called a virtual learning environment. From proprietary monolithic platforms, LMSs evolved into component-based, standard-supporting, centralized learning environments — former implementations of LMSs such as Moodle (http://moodle.org), dotLRN (http://dotlrn.org), and Blackboard (http://blackboard.com) followed this pattern. In particular, they took into account different users' heterogeneous needs by using adaptive hypermedia[1] and intelligent tutoring systems.[2]

However, in the past seven years, researchers have defined some new and sometimes disruptive approaches to e-learning architectures. In this article, we place these trends in two families: those that define a service-oriented LMS and those that propose the architecture of a personal learning environment (PLE). Both families are nonorthogonal in that service-oriented concepts aren't restricted to LMSs but can also apply to PLEs; the main difference between them isn't their modular design but whether they use a central management system. According to Declan Dagger and his colleagues, for example, next-generation e-learning platforms will apply service frameworks to their modular design, support-

1089-7801/10/$26.00 © 2010 IEEE

ing the idea of an LMS composed by integrating interoperable services.[3]

However, Scott Wilson and his colleagues focus on PLEs, letting users apply Web 2.0-style services to create their own learning management tools.[4] Charles Severance and his colleagues combine the concepts of both families, applying PLE-style approaches to a mashup-based LMS — here, the LMS shrinks to become a much simpler container that joins and organizes the capabilities of a wide range of tools around a particular learning context.[5] This combination of concepts in both families relies on learner-generated contexts (http://learner-generatedcontexts.pbwiki.com) as well as peer-to-peer learning management and groupware systems such as Colloquia (www.colloquia.net).

Here, we present an additional way to combine the benefits from centralized service-oriented LMSs and PLEs by defining a service-oriented personalized e-learning environment. We also identify and define some open issues, along with the results of our proposed architecture's implementation.

Current E-Learning Trends

As we mentioned earlier, one of the first approaches to a next-generation e-learning architecture decomposed a central LMS into a service-oriented e-learning platform.[3] Dagger and his colleagues believe that separating LMS and learning-content-management-system (LCMS) functionality provides support for greater interoperability, in which systems not only share content and learning scenarios but also exchange tools, functionalities, semantics, and control seamlessly and dynamically. This definition disconnects new, innovative services and their applications to e-learning from a particular central LMS technology. In fact, in this service-oriented architecture, a system developer can implement a new LMS platform simply by using a new set of different, open e-learning services.[6]

The standards community has made some strides in defining a service-oriented e-learning platform. The IMS Abstract Framework (www.imsglobal.org/specifications.html) identifies and represents the core components and interfaces. The E-Learning Framework (ELF; www.elframework.org) illustrates e-learning systems' common functionalities; similarly, the Open Knowledge Initiative (OKI; www.okiproject.org) defines service layers for developing e-learning platforms. All these efforts decompose the different functionalities in a traditional LMS into a set of services and identify the methods required for a distributed interface to access such functionality. They also subdivide services into several categories, including basic services provided by the e-learning infrastructure (such as HTTP), common services required in all e-learning environments (such as authentication, file sharing, or logging), and specific application services (such as quizzes or simulations).

The service-oriented LMS offers many important benefits compared with the conventional monolithic LMS. For example, it provides a more flexible architecture in which instructors can add and use new services dynamically. Instructors can also integrate outside expert knowledge into courses offered on that platform via distributed interfaces; alternatively, system developers can reuse code across every learning platform because of the code's distributed nature.

Students will no longer passively consume learning materials but actively create and disseminate knowledge.

Another approach we mentioned earlier defines a PLE in which every user builds his or her own learning path by using available services on the Internet. Downes expects to see more research examining the concept of "e-learning 2.0," in which users apply popular social networking tools to e-learning processes.[7] The traditional asymmetric learning environment, with its clear distinction between the roles of instructors and students, will become more symmetric and based on communities of practice. Students will no longer passively consume learning materials but actively create and disseminate knowledge. PLEs emphasize symmetric connections with a range of services in both formal (instructor-led) and informal (student-led) learning, work, and leisure. Rather than integrating tools within a single context, PLEs coordinate connections between users and a wide range of services offered by organizations and other individuals.

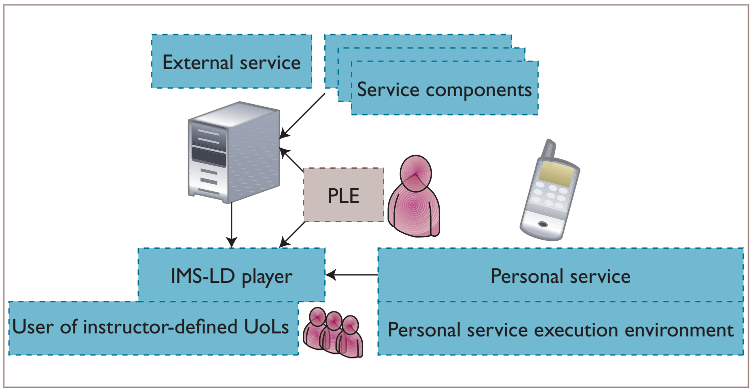

Figure 1. A service-oriented personalized e-learning environment. The user in the center consumes external e-learning services orchestrated by an IMS-LD.

Personal e-learning environments are well adapted to the life-long learning needs of our current IT-based society. They provide the required flexibility each user wants, especially as users adapt tools to a particular context. Life-long learning requires users to develop their own competences, so the TENCompetence consortium is developing a domain model to address this need.[8] For specific courses, adaptive hypermedia systems[1] and intelligent tutoring systems[2] offer alternative approaches by developing systems that can adapt to individual user goals, tasks, and interests. Integrating intelligent tutoring systems with personal e-learning environments might combine short- and long-term user adaptation (the EU's Adaptive Learning Spaces project [ALS; www.als-project.org] has done some preliminary research).

Although related to the PLE concept, a third approach incorporates learner-generated contexts and peer-to-peer systems to share resources. Hubert Vogten and his colleagues developed an implementation that follows these principles.[9]

Although learning institutions involved in formal learning courses might prefer the merits of a centrally controlled service-oriented LMS, time-constrained users might find PLEs and learner-generated contexts more flexible and adaptable to their needs. Dagger and his colleagues explain that service-oriented LMSs can still benefit from the availability of new open e-learning services, but Wilson and his colleagues leave LMS needs out of the e-learning picture. Although PLEs can plug e-learning services into a learner-controlled environment,[5] it's important to provide flexible mechanisms for learner-to-learner collaborative interactions.[9] Our proposed architecture allows both user- and instructor-controlled learning processes. Using community-defined units of learning isn't a new concept,[9] but our architecture enhances an IMS-LD (www.imsglobal.org/learningdesign/) controllable learning process with the reproduction of instructor-, community-, or user-defined units of learning that might contain pluggable external services.

Defining a Service-Oriented Environment

Ultimately, next-generation educational systems should emphasize the use of external services and be adaptable for both formal and informal learning. They should also capture mechanisms to define competencies and provide community-agreed orchestrated paths for acquiring them. Finally, they should separate the central orchestration point or LMS from the external e-learning services available on the Internet.[7] In this section, we describe how our service-oriented personalized e-learning environment tries to meet all these goals. Figure 1 shows our proposed architecture.

The central element is the user, who runs a PLE to access external e-learning services. This PLE is actually an aggregator of different services available from different communities.[5] These services can be independently provided either by the user (personal e-learning services) or third parties. They can also be orchestrated by a central coordinator tasked with providing user-, community-, or instructor-defined learning designs. Our architecture uses IMS-LD to define these learning designs. Using IMS-LD, our architecture can orchestrate any service as long as it uses a Web service-based interface. To provide a modular architecture, our proposal decomposes e-learning services into service-reusable components.[3]

Each service in Figure 1 follows a modular architecture that defines two independent interfaces for the service.[10] The user-oriented interface provides direct service access and user-to-user interaction, which simplifies creation of ad hoc learning communities. The programmatic interface creates a path for service integration in a common player tool that the user can control or that an instructor-defined learning path can centrally manage. The architecture described in an earlier paper is modular

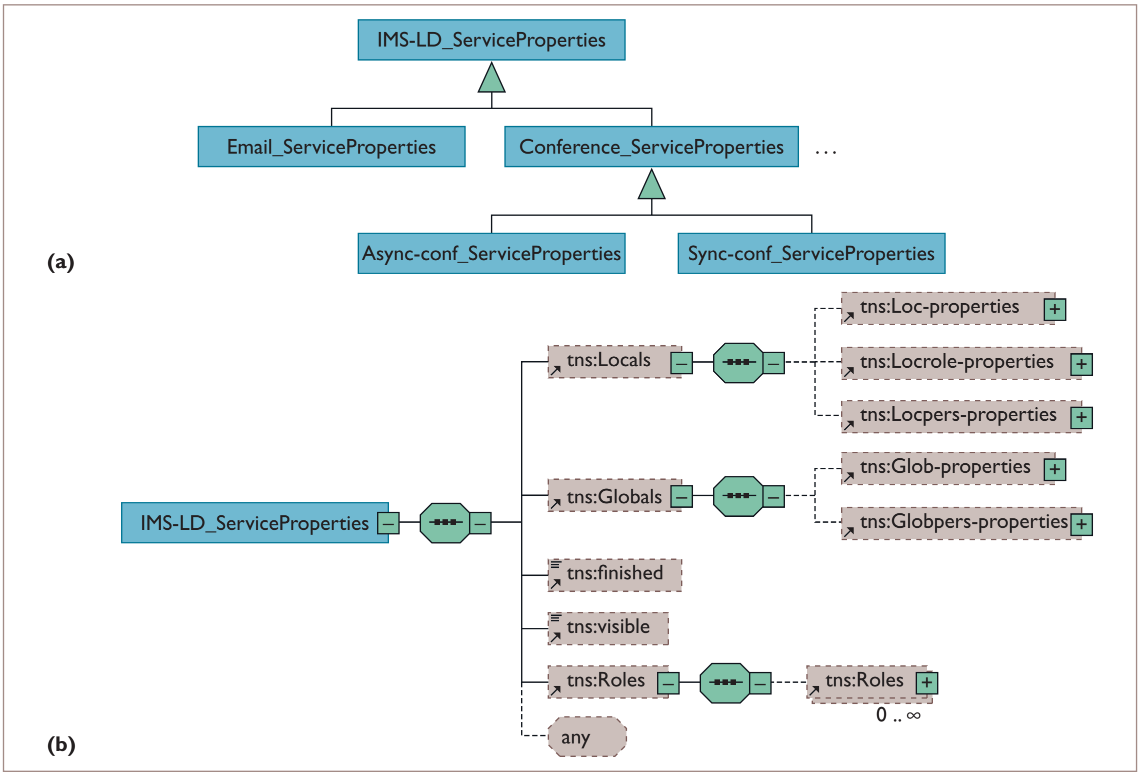

Figure 2. E-learning service hierarchy and resource properties document. (a) E-learning services are organized in a hierarchical tree of services. The figure shows some of the basic e-learning services in that tree. (b) The state of each e-learning service is captured in a resource properties document. The figure captures the state-dependent data of the generic e-learning service on top of the hierarchy.

in that it separates the common functionalities required by different services into distributed service components.[10] Defining service components in service-oriented architectures is a common practice on the Internet (OpenID [www.openid.org] and the del.icio.us API [http://del.icio.us/help/api/] offer two examples) and in e-learning in particular.

Figure 1 also shows our architecture's concept of a personal service execution environment (PSEE), which is associated with the execution of e-learning services on personal mobile devices. Through their mobile devices, learners become pervasive consumers of distributed learning resources and play an active part in the e-learning scenario, offering additional resources to other learners. Combining these devices either in a predefined or ad hoc manner, we can create personalized distributed learning architectures.

We designed the architecture in Figure 1 for life-long learning needs. Different users can join available Web 2.0 communities yet still control how they access and even execute e-learning services. Moreover, the architecture allows the creation of pedagogically enhanced platforms via IMS-LD's Web service-based interface, which makes e-learning services pluggable to external LMS-based or user-controlled players. Implementing an IMS-LD-compatible interface also makes it possible to integrate learning services into formal learning processes.

Defining this programmatic interface requires solving how to synchronize the execution state of each e-learning service and its representation inside the IMS-LD player and how to define and implement the methods the interface supports. We can categorize the states defined by an IMS-LD learning unit instance as

- level-B properties,
- implicit level-A properties,
- service initialization parameters, and
- execution environment-dependent states (such as the roles a particular user plays).

Among the different Web-related technologies for capturing state-dependent data,[11] we selected resource properties as defined in the Web Service Resource Framework (WSRF).[12] To

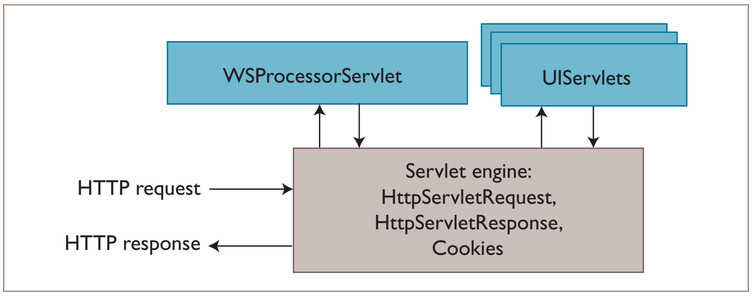

Figure 3. Simplified architecture of our implementation of an e-learning service. The user consumes the e-learning services using a servlet-based HTTP interface controlled by a servlet engine. The programmatic access to the services implements a Web services engine on top of the servlet engine.

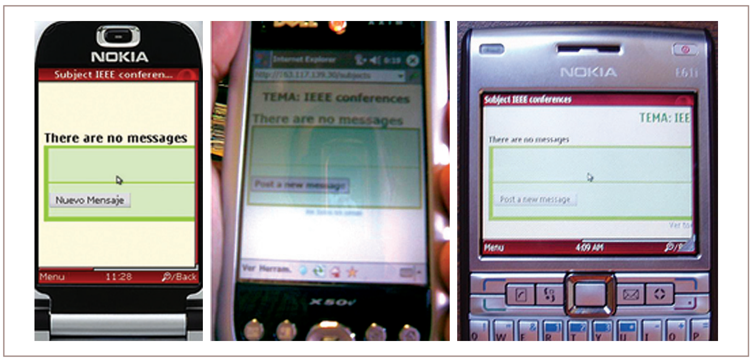

Figure 4. User interface for a forum service. The user interface is based on HTTP. The figure shows the visualization of a service on several browsers running on different devices.

provide a generic yet scalable architecture, we defined a hierarchical structure of e-learning services that our implementation translates into a hierarchical structure of resource properties.

Figure 2 captures part of the service hierarchy. Every new service can benefit from existing services by its inclusion in the hierarchy tree. Figure 2 also shows the root service's generic resource properties document, which captures the state that all IMS-LD synchronizable e-learning services share. Essentially, it contains both explicit and implicit properties as defined in a generic learning design.

Another issue involves how to provide e-learning services with the required capabilities for their inclusion in formal learning processes, which requires defining and implementing an IMS-LD programmatic interface. The WSRF defines Web service-based distributed middleware technology; accordingly, our architecture defines two WSRF-based interfaces. The first captures communication needs from the IMS-LD player to the distributed service; the second captures callback methods for the reverse path. Our service-oriented, pluggable architecture is designed to fulfill the requirements of both formal learning institutions and learners.

Implementing a Personalized E-Learning Environment

Pervasive personal e-learning environments should provide an anytime–anywhere learning scenario in which mobile personal devices play an important role. Our architecture encourages e-learning users to contribute to already established e-learning communities by sharing services such as blogs, personal files, and personal forums or syndicated channels running on their mobile phones and PDAs.

To integrate mobile services into externally defined units of learning, we need to implement the interfaces described in the previous section, which requires mobile devices to have Web service server capabilities. David C. Chu and M. Humphrey propose an implementation called OSGI.NET, a middleware layer for stateful Web services for Windows mobile devices.[13] However, this implementation isn't pervasive enough because it's limited to devices supporting a particular operating system. Similarly, another implementation described elsewhere is limited to Symbian devices.[14] To provide a non-operating, system-dependent implementation, we defined and implemented Web service development middleware in the J2ME MIDP profile (www.jcp.org/en/jsr/detail?id-271), which is based on a simplified servlet API implementation.

To validate our architecture's feasibility in general and deployment on limited mobile devices in particular, we implemented several personal e-learning services, including a personal forum. We divided the forum's architecture into three parts: the first maintains the dialogue with the user over a servlet-based graphical interface, the second is the implementation of the IMS-LD Web service, and the third is a service component for authentication based on the Open ID specification (http://openid.net/). Figure 3 shows a simplified architecture of the application.

Mobile devices often have HTML-based browsers, some of which are commercial and some of which are open source. Examples include Bitstream's Thunderhawk client (www.

bitstream.com/wireless/), Mozilla's Minimo Web browser (www.mozilla.org/projects/minimo/), and the Opera Mini browser (www.operamini.com). Figure 4 shows our forum service visualized in an Opera Mini browser on a simulated Nokia 6131 Near-Field Communication mobile device, in a Dell Axim X50v PDA running a Pocket Internet Explorer, and in a Nokia E61i running an Opera Mini browser. The forum service is also executed in a mobile device running J2ME.

The architecture we described here is open and service-oriented, enabling the integration of existing learning services, especially those built with Web 2.0 features and functionality. Here, we described its implementation with a sample pervasive e-learning service; we plan to run a trial with real users in the next year.

Acknowledgments

Spain's Programa Nacional de Tecnologías de la Sociedad de la Información supported this research through projects TSI2005-08225-C07-01 and -02.

References

1. P. Brusilovsky and M.T. Maybury, "From Adaptive Hypermedia to Adaptive Web," *Comm. ACM*, vol. 45, no. 5, 2002, pp. 31–33
2. T. Murray, "Authoring Intelligent Tutoring Systems: An Analysis of the State of the Art," *Int'l J. Artificial Intelligence in Education*, vol. 10, 1999, pp. 98–129.
3. D. Dagger et al., "Service-Oriented E-Learning Platforms: From Monolithic Systems to Flexible Services," *IEEE Internet Computing*, vol. 11, no. 3, 2007, pp. 28–35.
4. S. Wilson et al., "Personal Learning Environments: Challenging the Dominant Design of Educational Systems," *Proc. European Conf. Technology Enhanced Learning* (EC-TEL 06) *Workshops*, 2006, pp. 173–182.
5. C. Severance, J. Hardin, and A. Whyte, "The Coming Functionality Mash-Up in Personal Learning Environments," *Interactive Learning Environments*, vol. 16, no. 1, 2008, pp. 47–62.
6. P. Westerkamp, *Flexible E-Learning Platforms: A Service-Oriented Approach*, Logos Verlag, 2006.
7. S. Downes, "E-Learning 2.0," *e-Learn Magazine*, 16 Oct. 2005, p. 1.
8. R. Koper and M. Specht, "Tencompetence: Lifelong Competence Development and Learning," *Competencies in Organizational E-Learning: Concepts and Tools*, M. Sicilia, ed., Idea Group, 2006, pp. 230–247.
9. H. Vogten et al., "Using the Personal Competence Manager as a Complementary Approach to IMS Learning Design Authoring," *Interactive Learning Environments*, vol. 16, no. 1, 2008, pp. 83–100.
10. M. Muñoz-Organero and C. Delgado Kloos, "Pervasive LMS Components and Services for a Pervasive M-Learning Architecture," *Int'l J. Mobile Learning and Organisation*, Oct. 2007, pp. 275–287.
11. M.L. Bote Lorenzo et al., "Tailorable Collaborative Learning System that Combines OGSA Grid Services and IMS-LD Scripting," *Proc. 10th Int'l Workshop Groupware*, LNCS 3198, Springer, 2004, pp. 305–321.
12. T. Banks, *Web-Services Resource Framework (WSRF): Primer*, v. 1.2, Oasis, May 2006; http://docs.oasis-open.org/wsrf/wsrf-primer-1.2-primer-cd-02.pdf.
13. D. Chu and M. Humphrey, "Mobile OGSI.NET: Grid Computing on Mobile Devices," *Proc. 5th IEEE/ACM Int'l Workshop Grid Computing* (GRID 04), ACM Press, 2004, pp. 182–191.
14. D. Rocha, "Enterprise and Web-Service Programming for the Nokia Smartphone Platforms," *Forum Nokia Americas*, 2006.

Mario Muñoz-Organero is an associate professor of telematics engineering at the Carlos III University of Madrid. His research interests include open architectures for e-learning systems, open service creation environments for next-generation networks, advanced mobile communication systems, and pervasive computing. Muñoz-Organero has a PhD in telecommunications engineering from the Carlos III University of Madrid. Contact him at munozm@it.uc3m.es.

Pedro J. Muñoz-Merino is a visiting professor of telematics engineering at the Carlos III University of Madrid. His main research areas are e-learning and the Semantic Web. Muñoz-Merino has a PhD in telematics engineering from the Carlos III University of Madrid. Contact him at pedmume@it.uc3m.es.

Carlos Delgado Kloos is a full professor of telematics engineering at the Carlos III University of Madrid, where he's also associate vice chancellor, director of two master's programs (one on e-learning), and director of the Nokia Chair. His main research interest is educational technologies. Delgado Kloos has a PhD in computer science from the Technical University of Munich and a PhD in telecommunication engineering from the Technical University of Madrid. Contact him at cdk@it.uc3m.es.