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.

T he 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

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.