Modeling Context-Aware e-Learning Scenarios

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Abstract

In the last decade, e-learning has been introduced to a variety of blended learning scenarios, such as life-long learning, University lectures, and game-based learning. In all these scenarios the learner's situation or context is an essential asset in designing the learning process. Recent research suggests aiding the design process through the use of visual modeling approaches. Pervasive computing environments particularly call for extending these approaches in terms of enhanced context-awareness. This paper addresses these needs by introducing a UML-based modeling extension for explicitly including relationships between context and learning activities in the learning design models. The feasibility and applicability of our approach is demonstrated by a laboratory lecture case study, and respectively by a context-aware learning prototype that was developed using RFID technology for sensing of nearby persons and physical resources.

1. Introduction and Related Work

Visual modeling of real-world concepts is one of the primary means of reducing the complexity and cognitive load during the design stage of a system. As teaching and learning environments generally are ill-defined social systems [20], designing an e-learning course environment is a particularly complex process. Learning processes naturally take place in some kind of environmental context, which becomes more and more augmented with computing (pervasive and ubiquitous computing paradigm).

Recently, several approaches, like the well-known Educational Modeling Language (EML) [14], and others [2, 4, 13, 16] have emerged that aim at supporting this process by providing visual notations and formalisms that allow designers to create visual models of their course design. The main advantage of these visuals lies in reducing the complexity of e-learning scenario design, and in creating a medium for communication and documentation.

Few visual e-learning modeling languages use a standardized notation. One of them is the Person-Centered e-Learning (PCeL) pattern approach [7], which has been co-developed at the University of Vienna by one of the authors. It employs the Unified Modeling Language (UML) [21] for creating visual representations of course activity sequences, learning activity patterns based on the didactic principles of Person-Centered e-Learning [18], as well as structural relationships among different patterns and involved entities (e.g., persons, roles, documents, etc.). By adapting the pattern approach [1, 8], it facilitates the generation and implementation of flexible, modular, and reusable e-learning units, such as e-content publishing, online exchange and communication among students and teaching staff, self- and peer-evaluation of contributions, or online learning contracts [17]. In this paper, we use the PCeL approach to close the gap between the learning process model and the software model of context-aware e-learning applications.

None of the existing learning design modeling approaches – to the authors' knowledge – includes the learner's context in its visual models. However, integration of context is important because the learning environment implicitly influences the design of lectures and other learning processes, like for example, the provisioning of collaborative campus services [23] require a networked (often wireless) infrastructure, mobile devices, and public displays as provided by walls, beamers, or terminals. Even when designing a laboratory lecture, the resources necessary to solve the different learning units have to be considered. Additionally, being aware of the learner context supports situated selection and adaptation of learning units [24] and appropriate learning material and devices.

This paper proposes an innovative approach to include context information into the modeling of learning tasks at an early stage. Therefore, the paper adopts the PCeL modeling approach to define a generic learner context structure and to *explicitly* include this context information in the UML learning activity models in three different ways. As a consequence, the modeled learning units and thus, the e-learning applications derived and implemented can become context-aware in an almost natural way.

The paper is structured as follows: First, the concept is detailed containing a discussion of the PCeL approach, the context model used for e-learning, and the UML adaptations needed to model relationships between the context and the learning task. In section 3, a prototypical implementation shows the feasibility of our approach. Section 4 applies the approach to an example lecture and section 5 concludes the work.

2. Concept

2.1. Modeling Learning Patterns

The Person-Centered e-Learning (PCeL) patterns project [6, 7] introduced the use of the UML to model e-learning scenarios. The primary intent of the project is to provide generic scenarios (patterns) that are mined from previously successful e-learning courses, and to make them available for reuse outside their original context. PCeL pattern mining follows an inductive approach (cf. [3]): From UML activity diagrams of learning scenarios of several e-learning courses, frequently recurring (sub)scenarios are captured, modeled, and verbally described for documentation and dissemination. This inductive process is done manually by both researchers and practitioners. The central modeling aspect in the project is the capturing of learning activity sequences using standard UML activity diagrams: The primary elements are action states, which are used to model relevant activities related to the teaching/learning process in a course or pedagogy. The remaining model elements are mainly allocated to control the activity flow, i.e., decisions and either sequential or concurrent transitions.

The following subsection introduces a method of including context information in these course activity diagrams as a novel, useful extension to PCeL modeling.

2.2. Including Learning Context Information

The term *learning context* is used to describe the current situation of a person related to a learning activity. In addition to attributes relying on the physical world model (*world context*), like time and a 3D location, a variety of attributes implicitly or explicitly described by ontologies might be added to the context. When using an appropriate meta-modeling technique, like for example XML [25], the current situation might be compared with the requirements of any specific learning activity, which has been discussed, for example in [10].

Figure 1 presents the top level of an example hierarchical schema for a learning context. On the top level of the hierarchy, the categories *world context*, *physical context*, *digital context*, *device context*, and *learner information context* are identified.

The convergence of the physical and digital worlds establishes a *smart environment* [15] in which the *physical context* describes the learning resources (e.g., in terms of identification, category, name, and capabilities) and a list of persons (e.g., in terms of identification, name, and role). The *digital context* describes the digital learning resources currently available, like e-books, e-papers, simulators, and Web-based learning services. These attributes may change in case a learner connects to, or disconnects from, the Internet. Here, for example, IEEE LOM [11] can be used for modeling these parts of the context as learning objects.

The *device context* describes the hardware, the software, and the network connectivity of the e-learning device the learner is using. Some of these attributes are rather stable, while, for example, the network connectivity changes over time.

The *learner information context* describes the learner attributes. *Personal information* exhibits attributes like name, expertise, or interests. *Task specific information* includes attributes like progress or team membership. The attributes selected are an example sub-set of the attributes of the learner information general categories presented by the *IMS Learner Information Profile* [12], pp. 8–9.

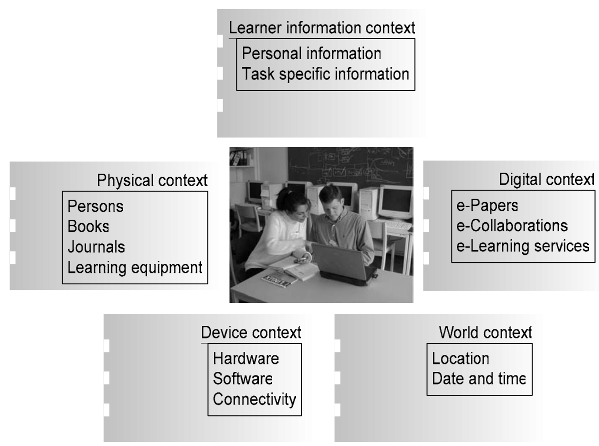

Figure 1. Top-level learning context description.

2.3. Context Modeling

The modeling approach presented in this paper aims at explicitly including the learning context in the learning activity models (LAM). Each concrete context object used in the LAM must represent an instance of some context class defined in the context structure model (CSM).

2.3.1. Context Structure Model (CSM)

As learner contexts are variant concepts that do not share a common closed structure across different application scenarios in different organizational settings, the structure of a context needs to be split up into:

(i) Universally applicable attributes. These include for example date/time and location.
(ii) Application-specific attributes. These have to be defined as by requirement of the modeler's application domain, e.g. attended lectures, learning progress, etc.

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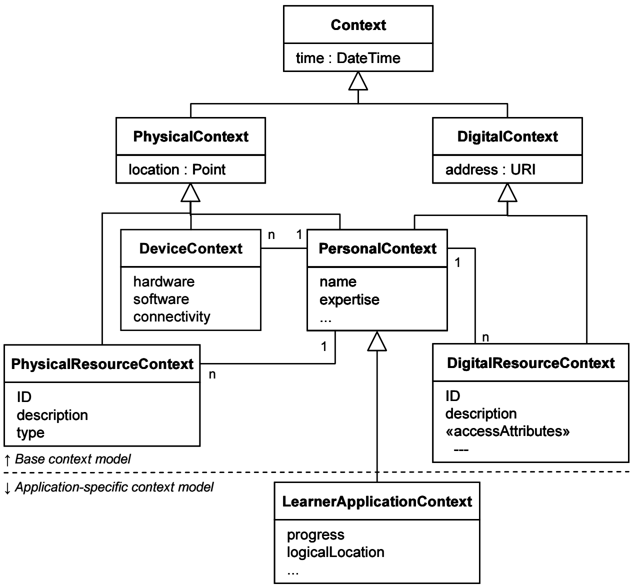

Figure 2. Context structure model.

The CSM defines a number of generic context classes (see Figure 2), which only include universally applicable attributes and which serve as base classes for application-specific context structures. Thereby, the modeler has to derive one or more custom context classes from the base structure, thus extending it to include required application-specific context classes and attributes. These custom context classes subsequently serve as templates for objects (i.e. context instances) modeled in the LAM. Figure 2 shows the base CSM above the dotted separator line, including a taxonomic, overlapping decomposition of *Context* into *physical* (resource, device, personal) and *digital* (resource, personal) context structures. The application-specific context class (i.e., *LearnerApplicationContext* below the dotted line), which serves as the context template for the example course LAM depicted in Figure 10, is derived from the base model's *PersonalContext* class.

2.3.2. Learning Activity Model (LAM)

Contextual knowledge is included in the LAM by annotating the learning activities with context objects. There are different options for considering context in learning design, namely from the process, the organizational, or the learner's point of view [19]. In our approach, the LAM shows primarily the learner's view on course activities. Nevertheless, the overall process (e.g., including the instructor's activities) needs to be co-considered to allow for constructing a complete, integrated course model.

In real environments context is always implicitly, concurrently present, which raises some problems in modeling a concrete instance of relevant context [22]. In the LAM, therefore, only relevant context changes as well as the influence of a context object on the "learnflow" (and vice versa) are modeled. At an abstract modeling level, three cases are differentiated:

(1) Activity updates context. For example, passing an exam updates the learner's context in a way that extends the learner's prior knowledge in the subject area. In such a case (generically depicted in Figure 3) a dependency relationship is drawn from the learning activity (*action state*) to the context object, optionally with the context update reason denoted as the dependency name.

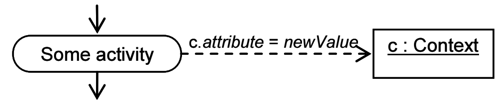

Figure 3. Activity updates context.

(2) Context alters activity. An activity is conducted with minor variations depending on some context's attributes. For example, the learner's current digital context may suggest the usage of an online learning object rather than a book on some topic. In such a case (Figure 4) a dependency relationship is drawn from the context object to the respective learning activity, optionally with a short statement about the particular influence on the learning activity depicted as the dependency name; or any constraining effect on the learning activity written in proper UML constraint form (i.e., expression enclosed in curly brackets).

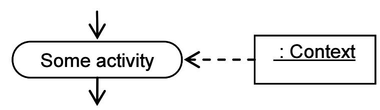

Figure 4. Context alters activity.

Note that an immediate combination of cases (1) and (2) resembles "*context flow*". In this case (Figure 5), a context update is a direct consequence of a learning activity, and that updated context object directly affects the subsequent activity. This relationship mirrors the semantics of "object flow", which is defined in the UML specification [21] as substitute for a simple transition.

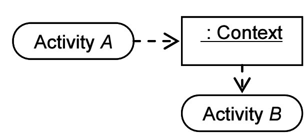

Figure 5. Context flow.

(3) Context as guard. The learner context guards the firing of one or more transitions between nodes in the activity diagram. In this case, the guard condition on the respective transition refers to some context object's attribute(s) using standard UML transition syntax (i.e., condition in squared brackets). Figure 6 shows a case where a context object acts as the decisive element for multiple possible control flows after a decision node.

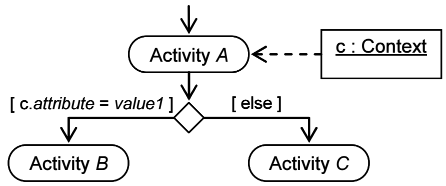

Figure 6. Context as guard.

3. Context-Aware Learning Demonstrator

Based on the learning activity model extensions presented in the previous Section, we now demonstrate how the relations between activities and learning context can be implemented. The prototype implementation assumes an indoor learning situation. In detail, WLAN support, laboratory equipment, books, persons attached with Radio Frequency IDentification (RFID) [26] tags, and RFID reader gates placed at room entries are assumed. The learning devices are tablet PCs, each attached with an RFID reader.

On the client side, which is used by the learners, the prototype focuses on visualization. The complete learning task is visualized (as UML activity diagram) and the learning progress is shown by means of Chernoff Faces [5] (here, defined face parts are used to visualize the multivariate data describing the learning progress in terms of success, timeliness, resource usage, and frequency of collaboration). The progress is determined by tracking of the learner's interactions. Physical resources and persons are visualized on a map depending on their sensed location and are augmented by additional information.

Depending on the current learning activity, the learner is supported by a description of the learning activity and its goal, by recommendation of learning resources (digital and physical), by recommendation of persons of interest for collaboration, and by an assessment facility. Additionally, the prototype supports chatting and messaging.

The current implementation of the prototype is based on Java, Java RMI, a JChernoff Face implementation [9], and MySQL. Learning clients can connect to a central server in a client/server communication style. Location and proximity sensing is based on RFID technology.

3.1. Activity Updates Context

The prototype implements this relation between activity and context when an activity is completed, that is, when the student solves the last sub-activity (for example, a test). This event causes an update of the learner's information context in terms of progress. The implementation of this case relies on updating of context object attributes. As a general requirement for implementation, each context object needs to expose appropriate methods for updating.

Figure 7 shows a cut-out of an example learning task, where *learning activity 1* has just been completed. The cut-out of the Chernoff Face visualizes the learner's behavior during learning activity 1 in terms of timeliness, frequency of collaboration, learning resource usage, and success.

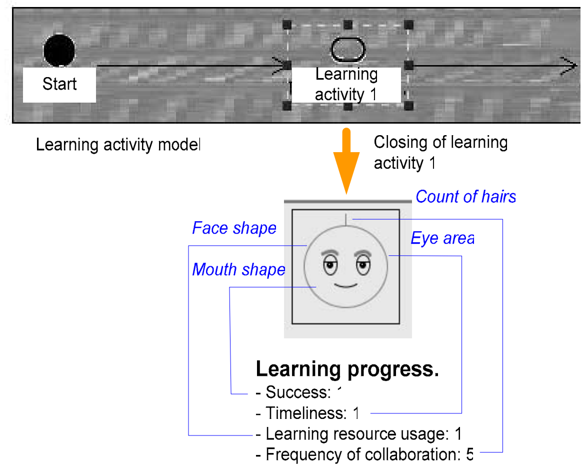

Figure 7. Activity updates context: cut-out.

3.2. Context Alters Activity

Depending on the current context, some activities might be altered slightly. The prototype implements this relationship by changing the activity-based recommendation of physical learning resources or persons (for collaboration) depending on location information. Implementations of this case will mostly employ the publish-subscribe pattern, i.e., a learning activity subscribes to a context object, which in turn publishes alterations to the learning activity.

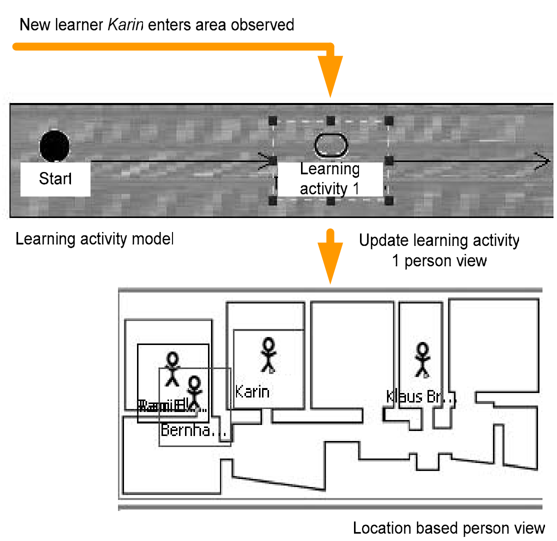

Figure 8. Context alters activity: cut-out.

Figure 8 shows persons involved in a collaborative activity (*learning activity 1*). The activity recommends collaboration partners by drawing red boxes around their avatars and by invoking additional collaboration support. When the person *Karin* enters the laboratory, the context-aware learning client is notified and the avatar is placed onto the map. Since Karin is a recommended collaboration partner for learning activity 1, the activity changes its *location based person view* by drawing a red box around her avatar and by including her into the collaborative learning activity. The same principle applies to physical resources, as well as to digital resources depending whether connectivity allows or restricts access.

3.3. Context as Guard

Using 'context as guard' to choose from different learning activities is a more coarse-grained option to alter a learning task. Depending on the context, the selection of alternative learning activities is provided. (Note that the same notation is used for cases where the learners may take the decision manually.) Regarding implementation, context objects simply need to expose context information retrieval methods, which will be invoked by the control flow thread.

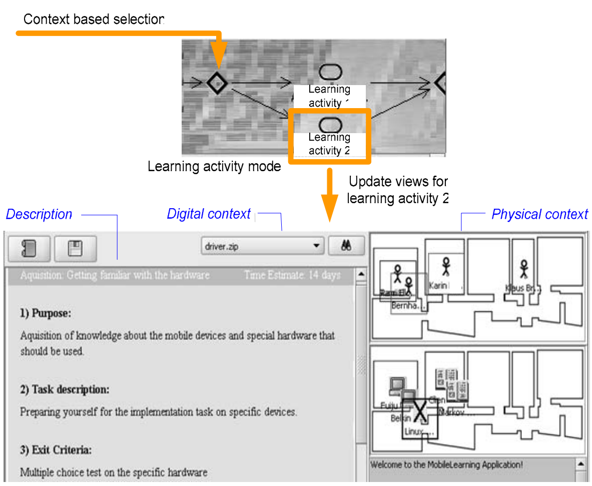

Figure 9. Context as guard: cut-out.

In our prototypical setting (Figure 9), the location is used as selection criteria. A learner might enter a seminar room where an introductory lecture is given (resulting in selection of *learning activity 1*), or she stays at the computer laboratory preferring self-study and non-structured collaborations with other persons around (*learning activity 2*). Learning activity 1 and 2 differ in the services provided, assessment strategy, and resources needed.

4. Case Study: Laboratory Lecture

In this section, our approach is applied to a University laboratory lecture in the computer science curriculum which was held at the University of Vienna in summer term 2004. The lecture is based on the problem-based learning approach. Teams consisting of up to five students work on different, complex problems and applications. Figure 10 shows an UML activity diagram for the highest level (that is, the least detailed level) of the lecture from the learner's perspective.

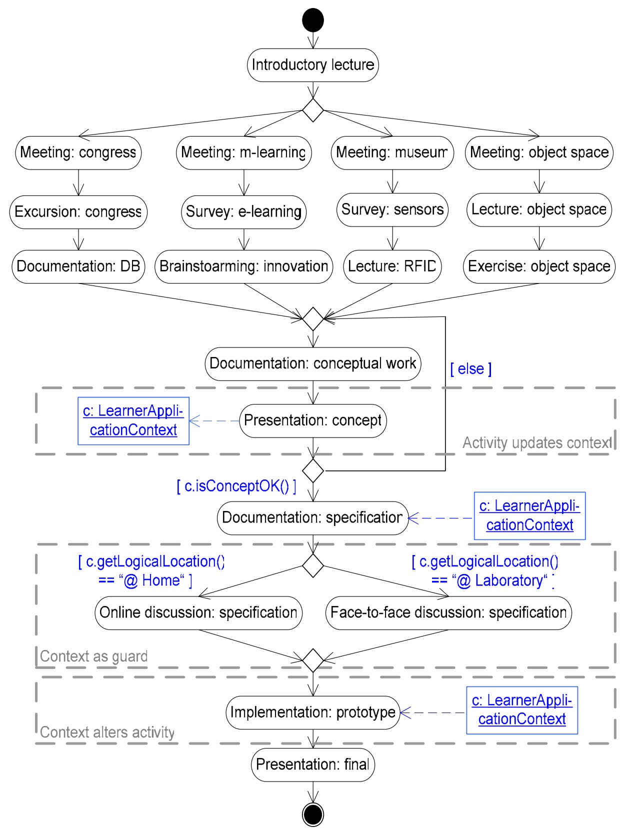

Figure 10. The laboratory lecture use case.

After the first introductory lecture which includes a formation of the teams, each team starts to acquire knowledge about the problem field (and thus, they have to work based on different learning activities). After these alternative activities have been passed, all teams work on the concept. Here, the student's learning information context is altered in terms of progress. Thus, the relation *activity alters context* is used (note that the student's progress is altered every time an activity is completed – for simplicity reasons we show this only for one example activity).

After that, students elaborate their prototype specification. A few activities are spent on discussion which can be done at home (where an Internet connection is assumed) via chat and messaging or at the laboratory (which means face-to-face). Here, the concept *context as guard* is applied. During the implementation phase, the students work on their applications using different hardware and software resources at the laboratory. The activities are slightly altered by the persons and resources nearby, thus, the *context alters activity* extension is used. At the very end of the course, students present and defend their work in a presentation meeting.

The application of this course is implemented by modular software components, which are derived from the course's learning activity model. Consequently, context-awareness is integrated into the entire development and application process.

5. Conclusion

We have presented a method of extending UML learning activity models with learning context information. A whole context-aware course or learning task and its underlying e-learning support modules can easily be modeled using the three proposed UML extensions. Our approach includes a generic context structure model that can be tailored to specific domains and educational environments by deriving custom context structures. Furthermore, we have presented how the relationship between context and the learning activity can be modeled. The use of the UML as a standardized formalism additionally furthers exchange, implementation support, and interoperability.

The applicability of our proposal has been demonstrated by a learning application prototype that utilizes the proposed modeling extensions to visualize and to provide proximity-based context-awareness to personal and physical resources based on RFID technology. Finally, we have shown the usability of the approach by providing a context-aware learning activity model of an advanced University laboratory lecture.

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6. References

[1] C. Alexander, S. Ishikawa , M. Silverstein, M. Jacobson, I. Fiksdahl-King, and S. Angel, *A Pattern Language - Towns, Buildings, Construction*. Oxford University Press, New York, 1977.

[2] AUTC, "Learning Designs," available at http://www.learningdesigns.uow.edu.au/, 2003.

[3] R. Baggetun, E. Rusman, and C. Poggi, "Design Patterns For Collaborative Learning: From Practice To Theory And Back," Proc. ED-MEDIA'04, Lugano, Switzerland, 2004

[4] L. Botturi, "E2ML - Educational Environment Modeling Language," Proc. ED-MEDIA'03, Honolulu, Hawaii, USA, 2003, pp. 304-311.

[5] H. Chernoff, "The Use of Faces to Represent Points in k-dimensional Space Geographically," *Journal of the American Statistical Association*, vol. 68, 1973, pp. 361-368.

[6] M. Derntl, "The Person-Centered e-Learning Pattern Repository: Design for Reuse and Extensibility," Proc. ED-MEDIA'04, Lugano, Switzerland, 2004, pp. 3856-3861.

[7] M. Derntl and R. Motschnig-Pitrik, "Patterns for Blended, Person-Centered Learning: Strategy, Concepts, Experiences, and Evaluation," Proc. ACM SAC'04, Nicosia, Cyprus, 2004, pp. 916-923.

[8] E. Gamma, R. Helm, R. Johnson, and J. Vlissides, *Design Patterns - Elements of Reusable Object-Oriented Software*. Addison-Wesley, Reading, MA, 1995.

[9] H. Herzog, "Multiple View Framework for Exploring Highly Structured Data." Vienna, Austria: Vienna University of Technology, 2004.

[10] K. A. Hummel, M. Ofner, B. Fiser, J. A. Mata Rodriguez, M. Seewald, and L. Pfeifer, "Context-Aware M-Learning Based on Meta-Learning Units," Proc. ICL'03, Villach, Austria, 2003

[11] IEEE LTSC, "Learning Object Metadata Workgroup," available at http://ltsc.ieee.org/wg12/.

[12] IMS Global Learning Consortium, "IMS Learner Information Package Specification - Final Specification, Version 1.0," available at http://www.imsglobal.org/profiles/lipinfo01.html, 2001.

[13] IMS Global Learning Consortium, "IMS Learning Design Specification," available at http://www.imsglobal.org/learningdesign/index.cfm, 2003.

[14] R. Koper and B. Olivier, "Representing the Learning Design of Units of Learning," *Educational Technology and Society*, vol. 7, 2004, pp. 97-111.

[15] J. Lai, A. Levas, P. Chou, C. Pinhanez, and M. Viveros, "BlueSpace: personalizing workspace through awareness and adaptability," *International Journal of Human-Computer Studies*, vol. 57, 2002, pp. 415-428.

[16] H. Lischka and R. Woitsch, "Knowledge Management and e-Learning: Integration of both disciplines in a top-down approach," Proc. ICL'03, Villach, Austria, 2003

[17] R. Motschnig-Pitrik, M. Derntl, and J. Mangler, "Web-Support for Learning Contracts: Concept and Experiences," Proc. m-ICTE'03, Badajoz, Spain, 2003

[18] R. Motschnig-Pitrik and A. Holzinger, "Student-Centered Teaching Meets New Media: Concept and Case Study," *IEEE Educational Technology & Society*, vol. 5, 2002, pp. 160-172.

[19] T. Nabeth, A. A. Angehrn, and R. Balakrishnan, "Integrating 'Context' in e-Learning Systems Design," Proc. IEEE ICALT'04, Joensuu, Finland, 2004, pp. 355-359.

[20] S. Naidu, D. Cunnington, and C. Jasen, "The Experience of Practitioners with Technology-Enhanced Teaching and Learning," *Educational Technology & Society*, vol. 5, 2002, pp. 23-34.

[21] OMG, "OMG Unified Modeling Language Specification, Version 1.5, March 2003," available at http://www.omg.org/cgi-bin/doc?formal/03-03-01, 2003.

[22] J.-C. Pomerol and P. Brezillon, "Dynamics between Contextual Knowledge and Proceduralized Context," Proc. CONTEXT'99, Trento, Italy, 1999, pp. 284-295.

[23] M. Rohs and J. Bohn, "Entry Points into a Smart Campus Environment - Overview of the ETHOC System," Proc. ICDCS'03, Providence, Rhode Island, 2003, pp. 260-266.

[24] A. Schmidt and C. Winterhalter, "User Context Aware Delivery of E-Learning Material: Approach and Architecture," *Journal of Universal Computer Science*, vol. 10, 2004.

[25] W3C, "Extensible Markup Language (XML)," available at http://www.w3.org/XML.

[26] Wikipedia, "RFID - Radio Frequency Identification," available at http://en.wikipedia.org/wiki/RFID.