

UPGRADE is the European Journal for the Informatics Professional, published bimonthly at <<http://www.upgrade-cepis.org/>>

Publisher

UPGRADE is published on behalf of CEPIS (Council of European Professional Informatics Societies, <<http://www.cepis.org/>>) by **Novática** <<http://www.ati.es/novatica/>>, journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática*, <<http://www.ati.es/>>)

UPGRADE monographs are also published in Spanish (full version printed; summary, abstracts and some articles online) by **Novática**

UPGRADE was created in October 2000 by CEPIS and was first published by **Novática** and **INFORMATIK/INFORMATIQUE**, bimonthly journal of SVI/FSI (Swiss Federation of Professional Informatics Societies, <<http://www.svifs.ch/>>)

UPGRADE is the anchor point for UPENET (UPGRADE European NETWORK), the network of CEPIS member societies' publications, that currently includes the following ones:

- **Informatica**, journal from the Slovenian CEPIS society SDI
- **Informatik-Spektrum**, journal published by Springer Verlag on behalf of the CEPIS societies GI, Germany, and SI, Switzerland
- **ITNOW**, magazine published by Oxford University Press on behalf of the British CEPIS society BCS
- **Mondo Digitale**, digital journal from the Italian CEPIS society AICA
- **Novática**, journal from the Spanish CEPIS society ATI
- **OCG Journal**, journal from the Austrian CEPIS society OCG
- **Pliroforiki**, journal from the Cyprus CEPIS society CCS
- **Pro Dialog**, journal from the Polish CEPIS society PTI-PIPS
- **Tölvumál**, journal from the Icelandic CEPIS society ISIP

Editorial Team

Chief Editor: Llorenç Pagés-Casas
Deputy Chief Editor: Francisco-Javier Cantais-Sánchez
Associate Editor: Rafael Fernández Calvo

Editorial Board

Prof. Wolfried Stucky, CEPIS Former President
Prof. Nello Scarabottolo, CEPIS Vice President
Fernando Piera Gómez and Llorenç Pagés-Casas, ATI (Spain)
François Louis Nicolet, SI (Switzerland)
Roberto Carniel, ALSI – Tecnoteca (Italy)

UPENET Advisory Board

Matjaz Gams (Informatica, Slovenia)
Hermann Engesser (Informatik-Spektrum, Germany and Switzerland)
Brian Runciman (ITNOW, United Kingdom)
Franco Filippazzi (Mondo Digitale, Italy)
Llorenç Pagés-Casas (Novática, Spain)
Veith Risak (OCG Journal, Austria)
Panicos Masouras (Pliroforiki, Cyprus)
Andrzej Marciniak (Pro Dialog, Poland)
Thorvaldur Kári Ólafsson (Tölvumál, Iceland)
Rafael Fernández Calvo (Coordination)

English Language Editors: Mike Andersson, David Cash, Arthur Cook, Tracey Darch, Laura Davies, Nick Dunn, Rodney Fennemore, Hilary Green, Roger Harris, Jim Holder, Pat Moody, Brian Robson

Cover page designed by Concha Arias-Pérez and Diego Blasco-Vázquez

"Abacus" / © CEPIS 2008

Layout Design: François Louis Nicolet

Composition: Jorge Liácer-Gil de Ramales

Editorial correspondence: Llorenç Pagés-Casas <pages@ati.es>

Advertising correspondence: <novatica@ati.es>

UPGRADE Newsletter available at

<<http://www.upgrade-cepis.org/pages/editinfo.html#newsletter>>

Copyright

© Novática 2008 (for the monograph)

© CEPIS 2008 (for the sections UPENET and CEPIS News)

All rights reserved under otherwise stated. Abstracting is permitted with credit to the source. For copying, reprint, or republication permission, contact the Editorial Team

The opinions expressed by the authors are their exclusive responsibility

ISSN 1684-5285

Monograph of next issue (August 2008)

"EUCIP: A Model for Definition and Measurement of ICT Skills"

(The full schedule of UPGRADE is available at our website)



The European Journal for the Informatics Professional
<http://www.upgrade-cepis.org>

Vol. IX, issue No. 3, June 2008

Monograph: Technology-Enhanced Learning (published jointly with Novática*)

Guest Editors: *Carlos Delgado-Kloos and Fridolin Wild*

- 2 Presentation. Next Generation Technology-Enhanced Learning — *Carlos Delgado-Kloos and Fridolin Wild*
- 6 Technology-Enhanced Learning: Supporting Learning in the 21st Century — *Pat Manson*
- 8 Integrating Web-Based and 3D Learning Environments: Second Life Meets Moodle — *Daniel Livingstone and Jeremy Kemp*
- 15 Game-Based Learning in e-Learning Environments — *Pablo Moreno-Ger, José Luis Sierra-Rodríguez, and Baltasar Fernández-Manjón*
- 21 Use of Folksonomies in the Creation of Learning Experiences for Television — *Marta Rey-López, Rebeca P. Díaz-Redondo, Ana Fernández-Vilas, and José J. Pazos-Arias*
- 27 Fostering Open Sensemaking Communities by Combining Knowledge Maps and Videoconferencing — *Alexandra Okada, Eleftheria Tomadaki, Simon Buckingham Shum, and Peter J. Scott*
- 37 Mobile Social Software for Professional Communities — *Ralf Klamma and Matthias Jarke*
- 44 Applying "Scruffy" Methods to Enable Work-Integrated Learning — *Stefanie N. Lindstaedt, Tobias Ley, Peter Scheir, and Armin Ulbrich*
- 51 Distributed Feed Networks for Learning — *Fridolin Wild and Steinn E. Sigurdarson*
- 57 Contextualized Attention Metadata in Learning Environments — *Martin Wolpers*
- 62 Free / Libre Open Source Software (FLOSS) Communities as an Example of Successful Open Participatory Learning Ecosystems — *Andreas Meiszner, Rüdiger Glott, and Sulayman K. Sowe*
- 69 New Objects in Formal Professional Learning: Replaying Meetings to Learn — *Linda Castañeda, Eleftheria Tomadaki, and Peter J. Scott*
- 76 UPC's Moodle Platform: A Study on Architecture and Performance — *Marcos Montero-Torres*
- 81 IFIP and TC 3 — *Jan Wibe*

UPENET (UPGRADE European NETWORK)

- 84 From **ITNOW** (BCS, United Kingdom)
Ethics in Computing
Robosoldier — *David Evans*

CEPIS NEWS

- 86 CEPIS Projects
Harmonise Outcomes — *Peter Weiß*
- 88 Selected CEPIS News — *Fiona Fanning*

* This monograph will be also published in Spanish (full version printed; summary, abstracts, and some articles online) by **Novática**, journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática*) at <<http://www.ati.es/novatica/>>.

Contextualized Attention Metadata in Learning Environments

Martin Wolpers

This paper presents the notion of Contextualized Attention Metadata (CAM) in learning environments. CAM describes observations about the handling of digital information in relation to the context in which the respective activities took place. The usage of CAM is exemplified in three scenarios: (i) using CAM to support the learning process of employees in agile business process execution, (ii) enriching learning resource description with CAM and (iii) identifying usage patterns of architectural learning resources with CAM. CAM helps to individualize the learning experience by providing detailed information about the learner's way of dealing with digital information which can be used, for example, to target the information provision to the learners needs by helping them to focus on the learning activities rather than on information management.

Keywords: Attention, Context, Contextualized Attention Metadata, Technology-Enhanced Learning.

1 Introduction

Information is plenty today. New technologies like Web 2.0 mash-ups further accelerate the number of information sources and the ways to interact with them. Learners spend significant amounts of time on continuously managing digital information that is either found (information pull) or provided (information push) through electronic means, e.g. via the Internet. In consequence, learning is severely hampered through the continuous distractions of managing provided content that increases the cognitive load of learners beyond meaningful states. New approaches are needed to support the learner, for example by individualizing and personalizing and thus enhancing the learning experience for each user. In order to facilitate such approaches, detailed information about the learner beyond common user profiles, so called Contextualized Attention Metadata (CAM), can be captured. One source of CAM is, for example, observations about the user's handling of information within digital learning and working environments. This paper describes in three scenarios how CAM can be used in different applications dealing with learning. The application of CAM exemplifies how the usage of CAM in learning environments can improve refocusing the learner on the learning task rather than the information management.

Section 2 describes how learning and attention are related while Section 3 reflects on the importance of the relation of context and attention. Section 4 gives an overview of the state of the art and outlines the identified challenges. Section 5 exemplifies addressing the challenges in a number of projects. The summary in Section 6 concludes the paper.

2 Learning and Attention

Learning in this context is seen as dependant on two distinct processing mechanisms, namely the information provision and the learning processes. The information provision is basically controlled by the information coming into the human cognitive system. The learner is requested to

Author

Martin Wolpers holds a PhD in electrical engineering and information technology from the Leibniz University Hannover. He is leading the group "Context and Attention for Personalized Learning Environments" at FIT ICON (Information in Context research department at the *Fraunhofer Institut für Angewandte Informationstechnologie*)¹, dealing with trend and user-goal identification from Contextualized Attention Metadata streams. Some of his stronger engagements in research projects are the project management position of the FP6 EU/IST TEL NoE PROLEARN and the leadership of the technical implementation team of the EC eContent+ MACE² project. His research focuses on how to use metadata to improve Technology-Enhanced Learning scenarios. In detail, he focuses on Contextualized Attention Metadata and Knowledge Representation in education. His further research interests deal with conceptual modelling, databases and information extraction. <martin.wolpers@fit.fraunhofer.de>.

process the information in a meaningful manner. Thus, in a given learning environment the learning processes rely on the person itself and which information and knowledge it already posses. For example, what learners already know, what they expect, their mental state, their previous experiences, their motivation, and so forth. All these information have been quite neglected in the development of learning technologies so far.

In order to deal with the incoming information, humans use filters to select only relevant information to process and disregard unwanted. The result of this selection is visible in the attention a learner gives to information. Consequently, being able to observe and measure attention enables a better tailoring of the information provision to the needs of the learner. For example, observing his attention will enable systems to help him in dealing with large amounts of incoming information by prioritizing and restricting them to those needed for the current task.

¹ <http://www.fit.fraunhofer.de/profil/bereiche/icon_en.html>.

² Metadata for Architectural Contents in Europe, <<http://www.mace-project.eu/>>.

3 Context and Learning

The attention of the learner is the result of one of the main selection processes of humans to reduce the amount of information to what is needed for the learning process. A further filter for the information provision is the learning environment used by the learner. Thus, to support the learner in his information acquisition process, the context in which he operates needs to be explicit and captured. For example, Learning Management Systems developed so far (e.g. Clix, Blackboard, Moodle) are highly specialized in supporting the user in specific tasks (e.g. acquiring a specific skill or competence) in specific environments. Consequently, such Learning Management Systems provide excellent sources of contextual information on the learning environment of the user, e.g. which course the learner is attending, which learning resources are read, which still need to be read, which communication is fostered with the other learners and teachers, etc.

While all this already yields highly useful information on the context of the learner, there is more information available: The learner usually operates in a much broader technical environment while learning, e.g. using non-learning environment internal tools and means of communication. Capturing such information extends the description of the context of learner significantly. Combining the information on the context with the observations about the attention of the user (in terms of his activities), contextualized attention metadata describes how a learner deals with specific information in specific contexts. Data about the information handling is captured from observations of user-driven activities like the handling of information on the computer and its location, but also from physiological observations like eye movement, skin-conductance and mouse-moving behaviour (mouse-gestures). The main focus is on utilizing the observations about and context of the learner to facilitate application and task independent support of individualized learning experiences. This includes a sound definition of context and contextualized attention.

4 State of the Art of Contextualized Attention Metadata

The current state of the art in user modelling is that data mining systems are used to mine data of a relatively simple nature (e.g. sequences of elements that are all of the same type), and that the mined models aim at relating users to predefined stereotypes [1]. This situation follows naturally from the state of the art in data mining: most currently available data mining methods (i) are indeed limited to analyzing data with a relatively simple structure, and (ii) work within a fixed context: for classification, the classes are predefined; for clustering, the similarity measure is predefined. There are numerous approaches to capture observations about the user attention; e.g. within the European projects Nepomuk, Aposdle, Gnowsis as well as others [2] [3][4] [5] [6]. These recent approaches attempt to observe and monitor the user in specified and restricted environments, e.g. online shops or learning management systems. The approaches make use

of the a priori definition of possible user stereotypes, activities and contents. Consequently, the models that capture contextual information are limited in terms of metadata about the contexts, the users and the contents. They allow for the correlation of captured information in their specific context. To address this shortcoming, approaches to broaden the scope and validity of user models emerged which enable the continuous update and exchange of pre-defined user models necessary to suite their fixed environments, e.g. [7]. Consequently, they are usually hard to adapt to changes in the users environment, newly available information, etc. Current research focuses on establishing interoperability between adaptive systems, e.g. within the EU/IST Grapple project.

Data about user experience with digital content (usage or attention metadata) describes what the user likes, dislikes, reads, publishes and listens to whenever he pays attention to digital content. So far, this rich source of information has not been deeply explored.

Current logging services such as Apache or Digital Libraries logging services, track what information users access, which errors users make while using systems, or from which countries users originate. This data provides limited information on the intention of the user. Furthermore, several formats are proposed to represent attention metadata, e.g. AttentionXML or Attention Profiling Markup Language (APML). All formats are targeted to specific applications thus capturing only specific attention metadata and hindering interoperability across applications and systems. Despite the fact that attention metadata is highly personal, recent and emerging approaches do not provide suitable means to ensure privacy and security of the data. Research in this area indicates that an approach like K-Anonymity [8] will yield the most secure results for the storage of such data, while encrypted and secured transmissions, e.g. via Secure Socket Layer (SSL) or secure Web services (e.g. proposed by the OASIS group) ensure privacy and security for the possible exchange of attention metadata. For example, track mechanisms for Web-browsing related attention metadata store the information in a way that other people can access it without appropriate security measures (e.g. AttentionTrust) while the owner cannot even modify or delete the data.

CAM also provides the ability to capture information from the content the user handles. Several approaches from the Semantic Web community provide first results in the area, mainly focussing on classifying information using existing ontologies. Combined with information from a more usage oriented point of view, e.g. at what times it was used, when and in which activities it was used, how it was classified (file folder and email folder structures), such content descriptions form an excellent source describing the context as well as the attention of a learner.

So far, no foundations have been formulated that describe the collection and processing of contextualized attention metadata (CAM) in total. Models exist that make use of certain aspects of CAM, but no overall model strives to capture all aspects to provide a holistic view on the user

and his activities. A first approach is described in [9] on work about the contextualized attention metadata schema.

5 Application of CAM in Real-World Scenarios

This section describes three early examples for the application of CAM in learning scenarios. The first example deals with the usage of observations about business process execution, the conclusions derivable from there and appropriate actions to improve efficiency and effectiveness of the business process execution. The approach outlined provides a suitable measurement to detect learning needs that occur through small functional or procedural changes in workflows. Please see [10] for an extended discussion (here we give a summative extract). The second example describes the usage of CAM for the enrichment of learning resource metadata. The third example briefly describes how usage metadata will be used in the MACE project to facilitate ranking of architectural learning resources. The examples give an outlook on the current status in respect to employing CAM in scenarios related to education.

5.1 CAM in Business Process Execution

Existing business process, learning and knowledge management infrastructures work quite well in their specific context. Despite this, such infrastructures are barely able to present any precise information about the usage of knowledge in certain working conditions, occurring learning needs or the identification of competency gaps and the detection of appropriate learning objects to fulfil the needs. Thus, the employees' qualification as well as the enhancement of their competencies constitutes an important precondition for an effective and efficient business process execution, the accomplishment of change management and their ability to anticipate cause-and-effect relations of process and market changes better and faster. To address the identification and provision of adequate (formal and especially informal) learning content in weakly structured or agile workflow environments, contextualized attention metadata can be useful.

A business process provides the context information necessary to identify learning needs and propose suitable learning resources respecting business and individual learning goals. The business process functions predefine the relevant information and supporting information systems as well as organizational and individual skill/competency references needed to operate in given business contexts.

Learning goals can be derived and trainings provided to ensure the (further) development of the employees' professional competencies and their process executing abilities based on these explicit pre-conditions. Recent observations indicate that most changes in workflows occur gradually. Participating functions in business processes usually are not completely exchanged but, instead, modified to suite the new workflows. Such modifications lead to activities that slightly change and therefore described as derivative functions. Business analysts from Aberdeen Group stated that the major problems of intrafunctional or procedural changes are the information of the employee involved respect the

provision of re-designed trainings. Nevertheless, suitable educational measures cannot be taken because, so far, no measurement exists to pinpoint the exact causes of the malfunctioning workflow. Instead, the employee is given a rather broad education to address the whole of the derived function. The training is not efficient and probably not effective because the employee already knows most activities relevant for the derivate function. The employees' real training need is embedded in the activities that change in the execution of derivate function while taking their experience and knowledge into account. So far, no Information and Communication Technologies tool exists to identify or derive training needs in a contextualized manner. The comparison of the observations with the function (type) definition describes the difference between real activities and required activities. Consequently, the gap defines the individual learning needs and also taking his knowledge and experience into account. Therefore, the combination of the observations about the employee with tacit knowledge about the workflow and function structure enables the deduction of learning needs.

5.2 CAM-Based Learning Lesource Metadata Enrichment

In this example, the combination of various types of metadata is used to enrich the metadata of learning resources to enable a more targeted and individualized provision of learning resources and thus enhancing the learning experience. The example is based on a proof of concept implementation realized in cooperation with the German Research Centre for Artificial Intelligence (DFKI), the Open University UK, the Ariadne Foundation and Fraunhofer Institute for Applied Information Technology. The proof of concept combines the social media platform ALOE with the Ariadne learning resource repository and the FlashMeeting repository.

The Ariadne repository uses expert-generated Learning Object Metadata (LOM) to describe learning resources. Specifically, the metadata fields representing semantic values are of interest, e.g., title, description and keyword as well as values representing educational information like difficulty or the interactivity type.

The FlashMeeting repository provides descriptions about recordings of FlashMeetings, including the title of the recording, a description, participants, keywords, a chatlog, etc. The descriptions are partly created by the organizer of the recording and partly captured automatically during the recording.

The ALOE system [11] is a social resource sharing platform following Web2.0 design principles. It allows users to share and organize bookmarks and arbitrary types of digital resources. Furthermore, arbitrary metadata sets can be associated with each resource. Thus, ALOE realizes a socially aware resource and metadata hub.

In this example, a user finds a specific learning resource from the Ariadne repository and adds it to the personal portfolio of learning resources in the ALOE system. The user

describes the resource through respective tags. Through the usage of user generated tags and the metadata of the resource, a suitable recording of a FlashMeeting is automatically found and suggested to the user. After viewing the recording, the user bookmarks the FlashMeeting and adds some tags.

This example describes how learning resource metadata can be enriched with valuable descriptions not available before. On the one hand the user describes the resources with tags that are added as personal keywords to his metadata set. If a number of users use the same keywords for a resource, and applying some simple clustering and weighting algorithms, such keywords can be clustered and weighted to ensure an appropriate measure for their relevance which enables better rankings.

On the other hand the user stores the resources in his bookmark folder. This fact implies that the resources are related with each other. If a number of users associate the same learning resources in the same way, the respective relations are also added to the metadata set of the learning resource and thus provide the bases for new relevancy measures.

Through the usage of CAM, the activities of the user are fed back to the Ariadne and FlashMeeting repositories to enhance the respective metadata descriptions. Furthermore, through the observations from all three systems, CAM allows to derive conclusions on the behavioural patterns and subsequently on trends while dealing with learning resources including the creating process within the repositories.

5.3 Usage Patterns of Architectural Learning Resources

The MACE project, funded within the eContent+ programme of the EU, aims to enhance architectural education in Europe by providing access to architectural learning objects using new approaches and advanced technology [12]. The learning resources are made accessible through an infrastructure of federated learning repositories. By correlating various types of content, usage, social and contextual metadata, the project provides access to the high quality architectural content through multiple perspectives and navigation paths that effectively lead to experience multiplication for the learner.

The MACE project will create a sustainable framework for structuring, connecting and exchanging architectural knowledge in Europe.

A focus of the MACE project is the utilization of contextualized attention metadata for advanced metrics and, subsequently, ranking approaches of architectural learning resources. Based on the work by Ochoa and Duval [6], metrics are developed to rank learning resources based on their usage within the MACE architecture as well as the respective repositories. For example, one simple metric bases on the number of views of learning resources.

Another, more advanced metric, correlates the dates of usage of the learning resources with each other thus gener-

ating a timeline of the usage per topic and relevant learning resources. The timeline is a first step towards the identification of possibly relevant usage patterns and trends.

6 Summary

Observing the learner in dealing with digital information provides a measurement on how the learner spends his attention on which information. Enriching these observations with information about the context provides contextualized attention metadata. Using CAM, elements of the learning process of the user can be much better tailored to his needs as the given example scenarios show. For example, CAM can help control the information provision within the learning process thus focusing the learner on the learning activities rather than on the information management.

First experiments hint that CAM enables the detection of so far undiscovered learning trends and tasks. The identification would be based on the correlation of observations of how a user is handling digital information in general. Being able to describe trends and tasks in terms of CAM will significantly improve the learning experience of users by enabling tools that directly target the needs of the learner instead of presumed needs as done in most of today's learning environments.

The research group "Context and Attention in Personal Learning Experiences" (CAPLE) at the Fraunhofer Institute for Applied Information Technology (FHG FIT) addresses the described research challenges in a number of projects. CAPLE aims to improve the individual learning experience by combining knowledge about the user, his context and relevant learning resources with advanced approaches for life-long learning. The focus is on individualization rather than recent mass personalization.

References

- [1] N. Henze, W. Nejd. "Logically Characterizing Adaptive Educational Hypermedia Systems". In Proceedings of the workshop on Adaptive Hypermedia and Adaptive Web-Based Systems, Session at WWW2003 conference, May 2003, Budapest, Hungary.
- [2] H. Holz, O. Rostanin, A. Dengel, T. Suzuki, K. Maeda, K. Kanasaki. "Task-based Process Know-how Reuse and Proactive Information Delivery in TaskNavigator". In Proceedings of ACM Conference on Information and Knowledge Management (CIKM) 2006, Washington, USA, November 2006.
- [3] S. Braun, A. Schmidt. "Don't Annoy the Informal Teacher: Context-Aware Mediation of Communication for Workplace Learning". In Proceedings of the 6th International Conference on Knowledge Management, Graz, Austria, September 2006.
- [4] J. Garofalakis, T. Giannakoudi, E. Sakkopoulos. "Semantic Web Site Usage Analysis: The ORGAN System". In Proceedings of the World Wide Web 2006 Workshop Logging Traces of Web Activity: The Mechanics of Data Collection, Edinburgh, UK, May 2006.

- [5] C. Roda, J. Thomas. "Attention Aware Systems: Theories, Application and Research Agenda". *Journal on Computers in Human Behaviour*, 22. 2006.
- [6] X. Ochoa, E. Duval. "Use of contextualized attention metadata for ranking and recommending learning objects". In *Proceedings of the 1st international Workshop on Contextualized Attention Metadata: Collecting, Managing and Exploiting of Rich Usage information*. CAMA '06. ACM, New York, NY, 9-16. 2006.
- [7] S. Sosnovsky, P. Dolog, N. Henze, P. Brusilovsky, W. Nejdl. "Translation of Overlay Models of Student Knowledge for Relative Domains Based on Domain Ontology Mapping". In *AIED 2007: 13th International Conference on Artificial Intelligence in Education*. LA, US, July 2007, IOS Press 2007.
- [8] L. Sweeney. "K-Anonymity: a model for protecting privacy". *International Journal on Uncertainty, Fuzziness and Knowledge-based Systems*, 10 (5), 2002.
- [9] M. Wolpers, J. Najjar, K. Verbert, E. Duval. "Tracking Actual Usage: the Attention Metadata Approach". *International Journal Educational Technology and Society*, Special Issue on "Advanced Technologies for Life-Long Learning". 2007.
- [10] M. Wolpers, G. Martin, E. Duval. "CAM in Process Execution". In *Proceedings of the 7th International Conference on Knowledge Management (I-Know)*, Special track on Integrating Working and Learning (IWL'07), *Journal of Universal Computer Science*, Graz, Austria, September 2007.
- [11] M. Memmel, R. Schirru. "Sharing Digital Resources and Metadata for Open and Flexible Knowledge Management Systems". In K. Tochtermann, H. Maurer (Eds.), *Proceedings of the 7th International Conference on Knowledge Management (IKNOW)*, Graz, Austria, *Journal of Universal Computer Science*, 2007.
- [12] M. Stefaner, E. Dalla Vecchia, M. Condotta, M. Wolpers, M. Specht, S. Apelt, E. Duval. "MACE – Enriching architectural learning objects for experience multiplication". *Proceedings of the 2nd European Conference on Technology-Enhanced Learning (EC-TEL 2007)*, Crete, Greece, September 2007. In *Creating New Learning Experiences on a Global Scale*, LNCS, Vol. 4753, ISBN: 978-3-540-75194-6. 2007.