Ad-hoc Composition of Distributed Learning Objects using Active XML

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Abstract—**As digital content in the form of learning objects allows the assembling of learning material on the fly, developers and users strive to aggregate learning objects from different origins to coherent learning units in a consistent way, including graphical and navigational design. Such content elements that rely in distributed repositories require metadata for advanced search functionality to identify learning objects that fit learner's needs. Furthermore, the content has to fulfil the requirements of a standardized content structure to allow the integration and composition of learning objects to new learning material. In addition, a technology to connect the distributed repositories and exchange metadata and content is needed. In this paper we propose a system for ad-hoc learning object composition. It allows the linking of distributed repositories of learning content management systems (LMCSs), searching, requesting and retrieving learning objects, adapting them to the local LCMS, and finally, integrating the retrieved objects into a new learning material. Thus, our technology is able to query XML encoded metadata of learning objects and to transmit their content within a distributed peer-to-peer environment.**

Index Terms—**Learning object composition on-the-fly, Active XML, content adaptation, learning content management systems**

I. INTRODUCTION

The increased use of information and communication technologies to support learning has led to strengthened efforts concerning digital content production. Since digital content can easily be reused, the concept of learning objects (LOs) as fine granular elements for knowledge transfer has evolved rapidly. LOs allow content engineers to design modular and self-contained learning units, and recompose them to new courses that can be offered in e-learning environments [1].

With the advent metadata standards, such as LOM (http://ltsc.ieee.org/wg12/), a number of public LO repositories e.g. MERLOT) have emerged. So far, these repositories merely check metadata and deliver links to the actual content that has no standardised structure or data format (HTML, Flash, etc.). This is caused by an insufficient compliance with LOs structures according to learning material standards at design time. As a result "most of the LOs are individually designed and styled, and navigational and user interface controls are directly integrated into the LOs. Aggregating such LOs from different origins to larger coherent learning units is hardly possible, due to inconsistencies in the graphical and navigational design" [2]. Furthermore, once such LOs are stored in an unstructured way they can only be shared as a single entity. This approach of share and reuse is bound to fail [3]. A more component-oriented model would enable the seamless integration of document fragments from diverse origins [4]. It could also handle "content, presentation, and navigation" separately, which is considered to be crucial for design [3].

Besides file-based LO repositories learning content management systems (LCMS) have been developed for virtual course design. In this case LOs are structured in a standardized form and stored in local repositories [5]. But LMCS-LOs "are always distributed among several places, and thus cannot be effectively shared and reused (…), are system dependent and cannot combine with other learning systems" [6]. A system for ad-hoc LO composition that maintains the links between distributed repositories of LCMSs, *and* provides functions handling distributed search requests would overcome these problems. It should provide functions to search and retrieve LOs, adapt them to the local LCMS, and integrate the adapted LOs in order to form a new learning material.

Since XML is the most popular structuring approach to represent learning content and its metadata (cf. SCORM Content Aggregation Model, LOM Metadata Standard, etc.), the querying and retrieval of LOs has to be performed utilizing XML. Therefore, some technology being able to query the XML-encoded metadata of LOs and to exchange the actual content of these LOs in a distributed peer-to-peer environment is required. Since the technology *Active XML* is able to process and exchange XML structures and enriches them with active behaviour, it might overcome the limits of existing approaches as sketched above. Thus we will show how a system for ad-hoc LO composition in peer-to-peer settings can be realized using the technology Active XML.

In this paper the capabilities of Active XML are explored with respect to the ad-hoc composition of LOs. In section II we review various approaches to represent learning content, as well as concepts and systems for dynamic content development. In section III system requirements for ad-hoc LO composition are identified based on the findings in section II. The list of requirements allows us to identify Active XML candidates for implementation in section IV. In section V the architecture of an Active XML-system for ad-hoc LO composition is introduced based on a selected candidate. Section VI concludes the paper.

II. RELATED WORK

This section gives a brief overview of the related work. Firstly, developments to represent learning content are reviewed, concluding with the need for adaptation support (section II.A). In section II.B concepts and systems for dynamic content development are introduced.

A. Content Representation

Learning technology standards, such as IMS (www.imsproject.org), SCORM (www.adlnet.org), AICC (www.aicc.org) and LOM (ltsc.ieee.org) have incorporated concepts for content structuring and metadata definition in XML. The IMS standard provides the content packaging format for the organisation of LOs. A similar concept is also used by the popular SCORM standard, which provides two fine-grained components for content definition: *Assets* (text, media, images, sounds) and *SCOs* (Shareable Content Objects, collections of one or more Assets) which are part of the *Content Aggregation Model*. Schluep has compared the most popular approaches to standardizing content. He has shown that all concepts mutually correspond on the level of *LOs* which are *self-contained,* have a similar *size or granularity and* have a *standard structure* [2]. These characteristics allow the reuse "by a number of users in a number of different learning environments and also *allows them to be tailored and personalised* to meet *specific needs of different learners*" [7]. Likewise, the widespread LOM Standard (ltsc.ieee.org) has been designed to store metadata of LOs such as title, keywords, description, technical requirements, ownership, pedagogical attributes, interactivity type, and difficulty of a learning resource.

Each of the mentioned standards has been implemented in XML, since XML supports the separation of content and presentation, but also allows the abstraction to metadata [8]. Furthermore, XML in its pure form is rather static: Its structure does neither allow adaptation to learner needs [9] nor supports interactive elements [5]. Fraser and Mohan [10] also recognized that standards, such as IMS Learning Design and IMS Simple Sequencing, lack sufficient dynamic concepts, because "the paths through the learning material are pre-determined at design time." Consequently, dynamic approaches, such as Active XML, should be tested to bridge the gap between semantically rich structures and learner-sensitive adaptation.

B. Dynamic Content Development

One way to solve the above mentioned problems concerning the static nature of XML and consequent shortcomings is the concept of dynamic content composition. This concept provides users the opportunity to search and assemble LOs into new ad-hoc learning materials depending on their current needs. The most common way to search for learning content is to apply the search criteria on the LOs metadata. The above mentioned widespread LOM Metadata Standard (ltsc.ieee.org) has been developed to define LO metadata and subsequently can be considered to build the technical basis for well defined search of LOs. This metadata search can be applied to central and distributed repositories. Central approaches like MERLOT (www.merlot.org) are based on a single repository and provide a central point of access. They allow defining search criteria according to a certain metadata standard and refer LOs.

Decentralised approaches like Edutella (www.edutella.org) and POOL (Portals for Online Objects in Learning, www.edusource.ca) rely on peer-to-peer networks. The distributed repositories are linked on a client-server basis which allows for searching and retrieving remote content. Therefore, queries are sent to all peers, applied to all repositories and results are sent back to the initial peer. Thus, there is no need to administer a central repository or submit content to it. It also provides sufficient flexibility to allow each institution to use its favoured content structure [11].

Each of the above mentioned systems search metadata repositories and delivers a link to the actual content, which is not part of the repository itself. As a result, the content of these LOs cannot be integrated automatically into newly assembled learning material. In the following we will introduce a way to realize ad-hoc LO composition through a system that uses XML as data representation for metadata and content structuring of LOs. Furthermore, we will introduce Active XML as an approach to search and retrieve LO data in peer-to-peer settings.

III. REQUIREMENTS FOR AD-HOC LEARNING OBJECT COMPOSITION

A system for ad-hoc learning object composition has to connect the repositories of distributed LCMSs and has to provide functions to search LO metadata, to retrieve the LO content, and to enable its reuse at run-time automatically. Since different LMCSs use different LO content structures, functions to automatically integrate and adjust the content on-the-fly to the locally used LCMS have to be provided. This adaptation should be performed locally at each peer to enable the development of wrappers for different kind of LOs and LCMSs.

The system requirements for ad-hoc LO composition were derived from existing concepts of distributed LOs in P2P networks and the functions of systems that implement these concepts. The two major frameworks in this area are Edutella (with the query interface Conzilla) and POOL. For requirement identification the concepts and functions of the frameworks have been analysed, in particular looking for implementing ad-hoc LO composition. The derived requirements are listed in alphabetical order in Table 1. Sources of origin are given in (brackets):

IV. A QUEST FOR ACTIVE XML

Before we designed the ad-hoc LO composition (see section VI), we evaluated the different existing Active XML approaches and selected the most proper approach with respect to the requirements given in section III.

A. Participating Active XML Approaches

Although there are many different approaches to enrich XML with active behaviour, there is no widely accepted definition of the term "Active XML" and no guide on how to select a proper Active XML approach. Hence, we defined the following criteria the approaches had to meet to be taken into consideration for evaluation:

- The approach has to define active behaviour
- The data must be represented with XML
- The active behaviour must be activated within the XML data
- The result of the active behaviour must be XML data

Requirement	Description
Adaptation of learning content: (concept)	The content of all retrieved LOs must be integrated into a single learning material and adapted to the local LCMS to allow the import and processing of the content.
Dynamic XML: (concept)	A technology is needed that can integrate XML structures from different sources to build new XML documents.
Exchange of content: (concept)	Besides the search for metadata, the system must also provide a mechanism to exchange the content of LOs (allowing its reuse on a remote system).
LOM XML mapping: (concept)	Since users should not be obliged to define search criteria directly according to the allowed values of the LOM metadata specification, a mapping mechanism must transform the user input into values of the LOM metadata schema. This mapping must also be done in the opposite direction to present the user the resulting metadata consistently.
Mapping service: (Edutella)	The mapping service maps search criteria that are defined on a specific metadata schema (e.g. Dublin Core) to a different schema (e.g. LOM). Thereby each peer can use a different metadata schema to describe the LOs in its local repository.
Mediation service: (Edutella)	The mediation service sends LO queries to all peers of the network, integrates the results to an overall result and sends it back to the initial peer.
Query interface: (Conzilla)	The query interface provides the user the possibility to define LO search criteria, hand them over to the network to process the search and present its result.
Query service: (Edutella)	The query service applies the retrieved search criteria to the local repository and hands over the result to the mediation service to send it back to the calling peer.
Rights management: (POOL)	A basic rights management should allow the users to manage the accessibility of LOs. This is done by declaring the local LOs as private or public. Using this service each peer can decide which LOs in its local repository can possibly be accessed by remote systems.

Since the selected Active XML technology was utilized in a peer-to-peer architecture setting, the approach additionally had to enable the exchange of metadata and LOs in a distributed environment.

To the best of our knowledge five different approaches meet the above mentioned criteria: Abiteboul [12] [13] [14], Bonifati/Ceri [15] [16], Ishikawa/Ohta [17] [18] [19], Papamarkos [20] [21] and Schrefl/Bernauer [22].

B. Structured Comparison

To decide, which of the mentioned approaches was the most appropriate to meet the requirements for a system for ad-hoc LO composition we carried out a structured

comparison. Based on the list of requirements (see section III) 27 items have been developed and grouped into the topics "Active XML Functionality", "Architecture", "Data Management", "Communication", "Technology and Standards", and "Implementation". The decision was made by assigning judgements to existing functions ranging from positive, negative, helpful to obstructive for the implementation of the ad-hoc LO composition system. For each of the 6 clusters "1" means the approach is the most appropriate in this field – see results in Table 1.

Topic \ Approach	Abiteboul	Bonifati	Ishikawa	Papamarkos	Schrefl
Active XML	1	3	1	2	2
Architecture	1	1	1	1	1
Data Management	1	1	2	2	2
Communication	1	1	1	1	1
Technology and Standards	1	1	2	1	1
Implementation	1	3	1	2	3

Since the approach of Abiteboul could be identified as the most appropriate in all 6 clusters, there was no reason for further weighting to achieve an overall result. Thus the approach of Abiteboul can be seen as the most appropriate to fulfil our requirements for a system for ad-hoc learning object composition. The detailed evaluation and its results can be provided by the authors. Detailed information about the comparison can be found at [23].

C. The Approach of Abiteboul

The approach of Abiteboul [12] [13] [14] is based on a peer-to-peer network with no central element that controls or manages the communication between peers. All peers operate as content providers and content consumers. The communication is based on service calls that are embedded in XML documents and can return XML data which extends the XML document. These service calls specify the URL of a contacted peer, the name of the called service and its parameters. Thus a service call for every contacted peer of the network has to be created.

The software architecture of this approach is shown in Figure 1. Each time a service call in a document of the AXML storage is activated through an event an evaluator recognises its occurrence and hands over the call to a SOAP wrapper which sends it via a SOAP message to the corresponding peer. On the remote peer a SOAP wrapper receives the call and passes it to the evaluator who reads the called service from the AXML service definitions repository, replaces its variables with the actual parameters from the call and passes it to the XQuery processor. The processor applies the query to the local AXML storage. The resulting XML structure is then sent

back to the calling peer and integrated in the XML document of the call.
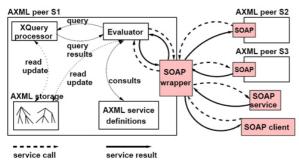

Figure 1.   Architecture of the approach of Abiteboul [14]

V. TECHNICAL PROSPECTUS

In this section the technical details of the software architecture and our prototype implementation of the concept are introduced.

A. Software Architecture

The software architecture is based on the implementation of the Active XML approach of Abiteboul (Figure 1) and is shown in Figure 2. It extends the basic architecture with a graphical user interface, an interface to an UDDI register, a LOM XML Mapper, learning material wrappers and an interface to the local LCMS. The functionnalities of the additional components with respect to the basic architecture in Figure 2 are described in Table 3.

To enable searching and distributing of LOs using this architecture, each peer has to keep the LOs as XML documents in the AXML storage and has to provide the services to search the storage in the service definition repository. Since Active XML can only process and distribute XML structures, the repository holds only the XML data of LOs which can include references to local media files as part of the content.
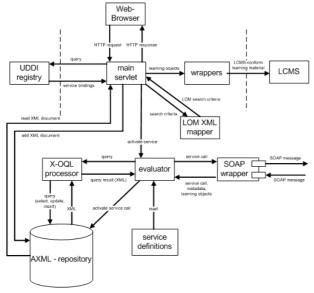

Figure 2.   Overall software architecture

As the referenced media files cannot be exchanged using Active XML, they remain on the remote server after the LO exchange process. Accordingly, all relative links

in the received XML data have to be transformed to absolute links to refer these files. Thus all media files remain at their initial location, and are only loaded at runtime from a remote system.

TABLE III
ADDITIONAL COMPONENTS FOR IMPLEMENTATION

Element:	Description:
User Interface:	The graphical user interface is based on HTML to be displayed in web browsers on different devices. It presents the search form for the input of the user's search criteria, lists the result of the search and enables the selection of found learning objects.
LOM XML Mapper:	The LOM XML Mapper transforms the users' search criteria into the corresponding XML-coded LOM metadata values that form the parameters of the service call and are the technical criteria for the search.
Wrappers:	The learning material wrappers convert the received LOs into the format the local LCMS can import and process.
Main Servlet:	The Main Servlet controls the entire composition process. It generates the user interface, searches the UDDI registry for remote peers, creates a search instance in the XML repository, activates the service calls, merges the received LOs, uses the wrappers to adapt the content and hands over the resulting learning material to the LCMS.
Interface Wrapper – LCMS:	After a wrapper has adapted the learning material to the local LCMS, the existing import function of the LCMS is called via an interface to hand over the content.
Interface Main Servlet – UDDI Registry:	Participating peers of the network have to join an UDDI registry and publish their URI in a service binding. Thereby all peers can determine the actual members of the network by querying the UDDI registry.

As a result of the search, the local peer repository contains XML data from all found LOs that satisfy the search criteria. The content can then be accessed by the local wrappers to integrate and adapt the LOs to a new learning material and import it in the local LCMS.

1) Peer-to-peer architecture

The approach of Abiteboul is based on a peer-to-peer network. It has no central element that controls or manages the communication between peers, because the communication is done via web services and web service calls. As these service calls contain the URL of the remote peers, communication occurs only between two network peers at a certain time.

To collect all the URLs of the participating peers, a UDDI registry is instantiated. In this registry, every institution can register itself as a peer by publishing its URL. This is implemented through a TModel defined in the UDDI. The key of the TModel is also published in the UDDI and can then be used by every institution to create a web service binding referring to the Tmodel. In this way, the local access URL of the peer is defined. At runtime, the UDDI register is searched by each peer to find out all service bindings that refer the TModel in order to retrieve the URLs of all currently participating peers.
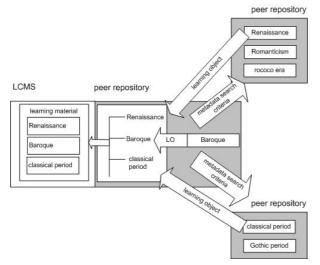
Figure 3. Basic peer-to-peer architecture

Each peer has to keep the LOs as XML documents in the AXML storage. It has also to provide the service definitions that are called by remote peers to search the AXML storage. Since Active XML can only process and distribute XML structures, the repository holds only the XML data of LOs. In the case of SCORM it is a single imsmanifest.xml file per LO that contains the content organisation and refers to files that contain the content. The system also implements content for the SCHOLION learning environment (http://scholion.jku.at). It contains content in XML completely, including references to media files as part of the content.

Since the service calls only return XML structures, the local repositories contain copies of the XML data of the Los. The actual media files remain on the remote server. Accordingly, all relative links in the received XML structures have to be changed to absolute links that refer to the media files that are stored on the remote servers. In this way, all media files remain at their initial location, and are only loaded at run-time from a remote system to the target peer.

As a result, the peer repository contains XML data from all LOs which can be accessed by the local wrappers to integrate and adapt the LOs to a learning material. It can be put into the local LCMS (cf. Figure 3).

B. Implementation

The above mentioned design was implemented in a prototype that utilises the SCORM 2004 2nd Edition Sample Run-Time Environment Version 1.3.3 (available at www.adlnet.gov/downloads/) as LMCS to display the composed learning material. The main reasons for this choice were its public availability, the use of the Apache Tomcat Server (also the basis of the AXML implementation of Abiteboul) and its open implementation in Java/JSP. The most straightforward way to integrate the AXML component was to run the AXML web application within the SCORM RTE web server. Since the SCORM RTE uses SCORM LOs we chose SCHOLION WB+ learning units [24] [25] as second type of LOs to show the wrapper functionality that merges and adopts different kind of LOs according to the above mentioned SCORM Content Aggregation Model.

1) User Interface

The query interface, which allows the user to define his search LOs according to certain criteria, is shown in Figure 4. The form entries "title" and "keyword" are text fields, whereas the input fields "language", "difficulty" and "interactivity level" provide pre-defined options.

Figure 4. Query interface of the prototype

The result of a search process shows the used search criteria, the contacted peers and the LOs that fulfilled the criteria (see Figure 5).

Figure 5. Results of the query process

As the implementation of the approach of Abiteboul and the SCORM RTE are the basic components of the concept, the remaining functions to realize the whole functionality have been built on top of them. The implementations of these additional components are described in Table 4:

TABLE IV
ADDITIONALLY IMPLEMENTED COMPONENTS

Element:	Description:
Main Servlet	The whole searching and composition process is controlled by the Main Servlet (cf. Table 3) that is implemented as Java servlet.
UDDI register:	For UDDI registering, the SAP UDDI Register (http://uddi.sap.com/) is used. This register is searched by a Java class that uses the inquiry interface of the register (http://uddi.sap.com/uddi/api/inquiry) to retrieve the URIs of the peers.
LOM XML Mapper:	The LOM XML Mapper is implemented by a Java class that uses rules (defined in XML) to assign names and values of the HTML input forms to names and values of the LOM metadata standard. The resulting XML structure is used as parameters of the service call.
Learning material wrappers:	The SCORM RTE can only import SCORM courses. Consequently, a wrapper (using XSLT) transforms all SCHOLION LOs to the SCORM structure and integrates all LOs (SCORM and SCHOLION) into one SCORM course that is ready to import into the RTE.

C. Meeting the requirements

In order to show that the designed architecture and its implementation in the prototype have met the requirements of a system for ad-hoc LO composition (see chapter III), Table 5 lists the results in the realm of achievements.

Since not all of the components of the architecture could be used and tested separately, due their intertwining with other components, we decided to perform black-box tests. Test cases for checking the requirements had to be defined. The fulfilment of a requirement was defined on an expected result for a given input. The input of the tests were search criteria that were entered by a user to search for LOs. The output of the system were on one hand LOs and their metadata, which formed the results of the peer-to-peer search process and, on the other hand the imported learning material in the local LCMS that formed the output of the composition and import process of the LOs.

The tests were carried out on a network of two peers. Both peers contained a predefined number of LOs in their local repository. These repositories were searched by 10 test cases that differed in a number of ways: type of search criteria used, number of search criteria used, number of LOs in the result, type of LOs in the result, repositories contacted to obtain a result, and the number and types of LOs that were imported in the local LCMS. In each test case the output of the prototype corresponded to the expected output previously defined. Hence, the tests were in line with the requirements on a system for ad-hoc LO composition, as defined in chapter 3.

VI. CONCLUSIONS AND FUTURE WORK

XML has become a widespread standard in eLearning and is used for different purposes, including metadata definition, structuring of learning content, and the learning content itself.

TABLE V
REQUIREMENTS AND RESULTS

Requirement:	Achievement:
Adaptation of learning content:	The adaptation of the learning content is performed by the learning material wrappers. They map the received LOs to the locally used LCMS
Dynamic XML:	The functionality of dynamic XML is implemented by combining the functions of the ActiveXML approach of Abiteboul.
Exchange of content:	The exchange of content is done by executing a service call in the AXML repository processed by the AXML peer.
LOM XML mapping:	The LOM XML mapping is realized by a special component (LOM XML Mapper) that transforms user input to LOM XML metadata values on the basis of rules.
Mapping service:	The mapping service is implemented by different service definitions on the different peers. Since these service definitions are defined locally, each peer can choose how to apply the received criteria to the local repository.
Mediation service:	The mediation service is implemented through the components of the AXML peer of Abiteboul. It integrates the query results from different peers in a single XML file.
Query interface:	The query interface is implemented by simple HTML forms.
Query service:	The query service is implemented by the X-OQL processor of the AXML peer that searches the local XML repository.
Rights management:	A basic rights management can be done by registring and unregistering the LOs in the AXML XML repository which makes them accessible or inaccessible by the query service.

The static nature of XML leads to flexibility problems, in particular when adapting content to the personal needs of learners. We showed that a system for ad-hoc LO composition using Active XML can solve these problems by providing users the opportunity to search for LOs, and create new learning materials by combining distributed learning objects and adapting them to the local LCMS.

However this concept only focuses on technical aspects to enable searching and retrieving distributed learning objects. In a next step the focus has to rely on how to use this architecture to compose semantically correct and consistent results. This can be achieved by adopting the concept of adaptive hypermedia to adapt the content according to the user's goals, interests and preferences [26] [27]. Another approach to ensure consistent content is the incorporation of pedagogical and didactical aspects in the content composition process. The IMS Learning Design (IMS LD, www.imsglobal.org/learningdesign) specification focuses on these didactic aspects of learning content by formally describing learning scenarios. This includes the definition of roles, activities, learning methods and the learning environment in a didactic concept of the content to enable a better adaption of the content to the individual learner.

REFERENCES

[1] D. A. Wiley, "Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy," The Instructional Use of Learning Objects, D. A. Wiley D. A., Ed. retrieved Oct 17, 2006 from http://reusability.org/read/chapters/wiley.doc

[2] S. Schluep, Modularization and Structured Markup for Web-based Learning Content in an Academic Environment, Aachen: Shaker. 2005.

[3] E. Duval, "We're on the road to…," in Proceedings of the ED-MEDIA 2004 World Conference on Educational Multimedia, Hypermedia and Telecommunications, L. Cantoni and C. McLoughlin, Eds. Lugano, 2004, pp. 3-5.

[4] K. Verbert, and E. Duval, "Towards a global component architecture for learning objects: a comparative analysis of learning object content models," in Proceedings of the ED-MEDIA 2004 World Conference on Educational Multimedia, Hypermedia and Telecommunications, L. Cantoni and C. McLoughlin , Eds. Lugano, 2004, pp. 202-208.

[5] R. Schulmeister, Lernplattformen für das virtuelle Lernen. Evaluation und Didaktik, München: Oldenbourg, 2003.

[6] C.-J. Liao and F. C. Ou Yang, "A workflow framework for pervasive learning objects composition by employing grid services flow language," in Proceedings of the 4th IEEE International Conference on Advanced Learning Technologies, Kinshuk, C. K. Looi, E. Sutinen, D. G. Sampson, I. Aedo, L. Uden, and E. Kähkönen, Eds. Joensuu, Finland, 2004, pp. 840- 841.

[7] J. Taylor, J. Slay, and F. Kurzel, "An ontological approach to learning objects," in Learning Objects: Applications, Implications, & Future Directions, K. Harman and A. Koohang, Eds. Santa Rosa, California: Informing Science Press, 2006, pp. 35-62.

[8] C. Süß, "Adaptive knowledge management: a meta-modeling approach and its binding to XML," in: 12. GI-Workshop Grundlagen von Datenbanken, H.-J. Klein, Ed. Kiel, 2000, pp. 101-105.

[9] P. Dolog, N. Henze, W. Nejdl, and M. Sintek, "Personalization in distributed e-learning environments," in Proceedings of the International World Wide Web Conference (WWW2004), New York, 2004, pp. 170-179.

[10] R. Fraser, and P. Mohan, "Using web services for dynamically re-purposing reusable online learning resources," in Proceedings of the IEEE International Conference on Advanced Learning Technologies (ICALT 2004), Joensuu, Finland, 2004, pp. 595-599.

[11] W. Nejdl, B. et al, "EDUTELLA: a p2p networking infrastructure based on RDF," In Proceedings of the 11th International World Wide Web Conference, Hawaii, 2002, pp. 604-615.

[12] S. Abiteboul, O. Benjelloun, I. Manolescu, T. Milo, amd R. Weber, "Active XML: peer-to-peer data and web services integration," in Proceedings of VLDB 2002, Hong Kong, 2002, pp. 1087-1090.

[13] S. Abiteboul et al, "Managing distributed workspaces with active XML," in Proceedings of VLDB 2003, Berlin, 2003, pp. 1061-1064.

[14] S. Abiteboul, O. Benjelloun, I. Manolescu, T. Milo, and R. Weber, "Active XML: A data-centric perspective on web services," in Web Dynamics - Adapting to Change in Content, Springer, 2004, pp. 275-300.

[15] A. Bonifati, S. Ceri, and S. Paraboschi, "Active rules for XML: A new paradigm for e-services," in The VLDB Journal 10 (1), pp. 39-47, 2001.

[16] A. Bonifati, S. Ceri, and S. Paraboschi, S. "Pushing reactive services to XML repositories using active rules" in Computer Networks 39 (5), pp. 645-660, 2002.

[17] H. Ishikawa, and M. Ohta, "An active web-based distributed database system for e-commerce," in Proceedings of the Web Dynamics Workshop, London, 2001.

[18] H. Ishikawa, and M. Ohta, "A decentralized XML database approach to electronic commerce," in Proceedings of the Fifth International Symposium on Autonomous Decentralized Systems (ISADS 2001), Dallas, 2001, pp. 153-160.

[19] H. Ishikawa, and M. Ohta, "Querying web distributed databases for XML-based e-businesses: requirement analysis, design, and implementation," in Proceedings of the Twelfth Australasian Database Conference (ADC2001), Bond University, 2001, pp. 60-67.

[20] G. Papamarkos, A. Poulovassilis, and P. T. Wood, "Event-condition-action rule languages for the semantic web," in Proceedings of the 1st International Workshop on Semantic Web and Databases (SWDB'03), Berlin, 2003, pp. 309-327.

[21] J. Bailey, A. Poulovassilis, P. T. Wood, "An event-condition-action language for XML," in Proceedings of the Eleventh International World Wide Web Conference (WWW2002), Honolulu, 2002, pp. 486-495.

[22] M. Schrefl, and M. Bernauer, „Active XML schemas," In Proceedings of the Workshop on Conceptual Modeling Approaches for e-Business (eCOMO) at the International Conference on Conceptual Modeling (ER), Yokohama, 2001, pp. 363-376.

[23] W. Wetzlinger, Komposition verteilter Lernobjekte mit Active XML. Johannes Kepler University of Linz, 2006.

[24] A. Auinger and C. Stary, "Embedding self-management and generic learning support into courseware structures," in Proceedings International Conference on System Sciences HICSS-35, IEEE, Hawaii, 2002, pp. 465-474.

[25] S. Fürlinger, A. Auinger, and C. Stary, "Interactive annotations in web-based learning environments," in Proceedings 4th International Conference on Advanced Learning Technologies, (ICALT'04), IEEE, Joensuu, 2004, pp. 360-364.

[26] P. Brusilovsky, A. Kobsa, J. Vassileva, Eds. Adaptive Hypertext and Hypermedia., Dordrecht, Netherlands: Kluwer Academic Publishers, 1998.

[27] P. Brusilovsky, O. Stock, and C. Strapparava Eds. "Adaptive Hypermedia and Adaptive Web-based Systems," in Proceedings of AH 2000 International Conference, Trento, Italy, August 2000.

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