

## The New Challenges for E-learning: The Educational Semantic Web

### Lora Aroyo

Technische Universteit Eindhoven, Department of Mathematics and computer Science  
5600 MD Eindhoven, The Netherlands  
Tel: +31 40 247 2765  
Fax: +31 40 246 3992  
l.m.aroyo@tue.nl  
<http://www.wis.win.tue.nl/~laroyo>

### Darina Dicheva

Winston-Salem State University, Department of Computer Science  
601 Martin Luther King, Jr. Drive, Winston Salem, N.C. 27110  
Tel: +1 336 750 2484  
Fax: +1 336 750 2499  
dichevad@wssu.edu  
<http://www.wssu.edu/~dicheva/>

### Abstract

The big question for many researchers in the area of educational systems now is what is the next step in the evolution of e-learning? Are we finally moving from a scattered intelligence to a coherent space of collaborative intelligence? How close we are to the vision of the Educational Semantic Web and what do we need to do in order to realize it? Two main challenges can be seen in this direction: on the one hand, to achieve interoperability among various educational systems and on the other hand, to have automated, structured and unified authoring support for their creation. In the spirit of the Semantic Web a key to enabling the interoperability is to capitalize on the (1) semantic conceptualization and ontologies, (2) common standardized communication syntax, and (3) large-scale service-based integration of educational content and functionality provision and usage. A central role in achieving unified authoring support plays the process-awareness of authoring tools, which should reflect the semantic evolution of e-learning systems. The purpose of this paper is to outline the state-of-the-art research along those lines and to suggest a realistic way towards the Educational Semantic Web. With regard to the latter we first propose a modular semantic-driven and service-based interoperability framework, in order to open up, share and reuse educational systems' content and knowledge components. Then we focus on content creation by proposing ontology-driven authoring tools that reflect the modularization in the educational systems, maintain a consistent view on the entire authoring process, and provide wide (semi-) automation of the complex authoring tasks.

### Keywords

E-learning, interoperability, concept-based WBES, educational Semantic Web

### Introduction

The Semantic Web vision significantly evolves the Web technology and advertises the opportunity to achieve seamless semantic understanding across cultures, time, geo-graphical borders, and technological platforms. The question is will this also bring us to the next evolutionary step for E-learning?

The Semantic Web offers new technologies to the developers of Web-based applications aiming at providing more intelligent access and management of the Web information and semantically richer modeling of the applications and their users. An important target for the Web application developers nowadays is to provide means to unite, as much as possible, their efforts in creating information and knowledge components that are easily accessible and usable by third parties. Within the context of Semantic Web, there are several hot issues, which allow achieving this reusability, shareability and interoperability among Web applications. Conceptualizations (formal taxonomies), ontologies, and the available Web standards, such as XML, RDF, XTM (XTM: XML Topic Maps <http://www.topicmaps.org/xtm/>), OWL, OWL-S (OWL-S: OWL-based Web service ontology), and RuleML (RuleML: The Rule Markup Initiative <http://www.ruleml.org/>), allow specification of

components in a standard way. The notion of Web services offers a way to make such components mobile and accessible within the wide sea of Web information and applications.

The research on e-learning and Web-based educational systems (WBES) tradition-ally combines research interests and efforts from various fields. Starting from the traditional Intelligent Tutoring Systems (ITS), moving towards Web-based and hypermedia systems, we witness a growing interest in applying adaptation and personalization of the information offered to the users (e.g. learners, instructors and educational content authors). A characteristic aspect of this move is the attention the application needs to pay to the specific individual user in order to tailor the growing amount of information, coming from various distributed and local sources, to the needs, goals, roles and tasks of the individual users. In an effort to serve better the needs of the education community WBES attempt to employ Semantic Web technologies in order to achieve improved adaptation and flexibility for single and group users (e.g. instructors, courseware authors and learners) and new methods and types of courseware compliant with the Semantic Web vision. This promising class of Adaptive Web-based Educational Systems (AWBES) forms the basis of the emerging Educational Semantic Web.

The goal of this paper is to present and analyze the main aspects and research trends concerned with the development of a homogeneous e-learning Web space, where various systems collaborate in their effort to satisfy the users' needs and in the same time use state-of-the-art Web technologies to bring the e-learning to the level of the modern society developments. Our aim is to provide a ground for the design of more process-, context- and user-aware systems that facilitate efficient learning delivery, authoring and consumption. We first present four main aspects for achieving interoperability among WBES, including: concepts and ontologies for adaptive WBES, modularized adaptive WBES architectures, educational standards for the Semantic Web, and Semantic Web educational services. Then we discuss the importance of efficient authoring support covering the three central lines in the authoring of adaptive concept-based WBES.

## **Interoperability of WBES**

Considering the constant increasing of resources on the Web (both static documents and functional components and software) it becomes almost impossible for the learners, authors and instructors to get an overview of all the available information relevant to their current needs, tasks, roles and goals. And even if they find some materials, which seem suitable, they are not able to assess completely whether the found content is entirely appropriate for their goals (for instructors) or current knowledge and cognitive state (for learners). Within the class of Web-based educational systems, a major role in various instructional contexts play the Educational Information Systems that are aimed at providing intelligent, task-centered information support for solving problems and performing learning tasks. Consequently, considerable effort is currently focused on defining frameworks and architectures to tackle issues of information sup-port from multiple perspectives. On the one hand, we do have the example of monolith Learning Management Systems (LMS), such as Blackboard (<http://www.blackboard.com/>) and WebCT (<http://www.webct.com/>), which on more or less superficial level cover various teaching, learning, and administrative activities and as a result provide Web-enhanced courses. On the other hand, we see multiple examples of specialized and effective educational systems and content providers, which support only one task/function within the entire educational process. Representatives of such systems are adaptive textbooks constructed with AHA! (De Bra et al., 2003), InterBook (Brusilovsky et al., 1998) and Net-Coach (Weber et al., 2001), or adaptive courses within ELM-ART (Brusilovsky et al., 1996), PAT (Ritter, 1997) and AIMS (Aroyo & Dicheva, 2001). There are also more global but still highly specialized efforts, such as ARIADNE (<http://www.ariadne-eu.org/>) and EdNa (EdNa: Educational Network Australia <http://www.edna.edu.au/edna/page1.html>) courseware-reusability frameworks that provide repositories of re-usable educational objects.

In order to support a richer set of educational functions and increase their effectiveness, such systems need to interoperate, collaborate and exchange content or re-use functionality. A key to enabling the interoperability is to capitalize on the (1) semantic conceptualization and ontologies, (2) common standardized communication syntax, and (3) large-scale service-based integration of educational content and functionality provision and usage. This view is supported also by Anderson & Whitelock' fundamental affordances for the Semantic Web: "The vision of the educational semantic web is based on three fundamental affordances. The first is the capacity for effective information storage and retrieval. The second is the capacity for nonhuman autonomous agents to augment the learning and information retrieval and processing power of human beings. The third affordance is the capacity of the Internet to support, extend and expand communications capabilities of humans in multiple formats across the bounds of time and space" (Anderson. & Whitelock, 2004).

Another semantic interoperability vision is given by Stuff & Motta, who envision “a multiplicity of community-based Semantic Learning Webs each with its own, perpetually changing ontologies, knowledge bases, repositories and ways of making sense of the world.”, where ontologies provide means for semantic communication within and across those “Knowledge Neighborhoods” (Stutt & Motta, 2004). Stepping on the above three factors for interoperability, we propose a powerful service-oriented framework to support efficient communication between component-based WBES (Dicheva & Aroyo, 2004).

The following sub-sections summarize the main aspects of adaptive WBES in the context of achieving interoperability in the Semantic Web.

### **Concepts and Ontologies in Adaptive WBES**

We see that currently a considerable amount of the research on knowledge-based and intelligent systems moves towards concepts and ontologies (Aroyo & Dicheva, 2002; Devedzic, 2001; Mizoguchi & Bourdeau, 2000; Vasilakos et al., in press) and focuses on knowledge sharing and reusability (Chen et al. 1998; Ikeda et al., 1997). In general, an ontology is used to de-fine the basic terms and relations in the domain. It also provides axioms as rules and constraints for manipulating and managing the terms and their relations within this common domain vocabulary. Ontologies allow the definition of an infrastructure for integrating intelligent systems at the knowledge level, independent of particular implementations, thus enabling knowledge sharing (Breuker & Bredeweg, 1999). Together with various reasoning modules and common knowledge representation techniques, ontologies can be used as the basis for development of libraries of shareable and reusable knowledge modules (which take the form of software components) (Aroyo & Dicheva, 2002; Dicheva et al., 2003). As a consequence the research that focused on ontologies offers tools and technologies for reusing and sharing of knowledge and hence helps intelligent educational systems to move towards semantics aware environments.

There are a number of concept-based AWBES already developed (Aroyo & Dicheva, 2001; Brusilovsky, 2004; Brusilovsky et al., 1998; Aroyo et al., 2003; Dicheva et al., 2004; Dolog et al., 2004; Weber et al., 2001), which typically include: concept-based (ontology-driven) subject domain, repository of learning resources, course (learning task) presentation, adaptation & personalization. The fundamental feature of these systems is the subject domain conceptualization. It supports not only efficient implementation of their required functionality but also standardization: the concept structure can be built to represent a domain ontology that provides a broadly agreed vocabulary for domain knowledge representation. Thus the ontology specifies the concepts to be included and how they are interrelated. The repository contains learning resources (objects) relevant to the defined subject domain concepts. We can think of the resources as being attached to the domain concepts they describe, clarify, or use. If the attached learning resources have also a standards-based representation as opposed to a system-specific internal representation, this will insure that the application’s content is reusable, interchangeable, and interoperable.

Course/learning tasks are typically described/annotated in terms of subject domain concepts and some instructional relationships (such as ‘prerequisite’, ‘uses’, etc) between the involved concepts. The domain concepts are also used as a basis for implementing systems’ adaptive behavior. The latter involves constructing learner models in terms of subject domain concepts, performed tasks, and user profile characteristics.

An AWBES user is typically involved in exploring the subject domain ontology and searching the repository for information related to a specific task. Good examples of such systems are AIMS (Aroyo & Dicheva, 2001) and TM4L (Topic Maps for Learning) (Dicheva et al., 2004). AIMS and TM4L both focus on providing contextual support that enables learners to identify information necessary for performing a specific task (e.g. course assignment). Since both focus on efficient information provision and support for task-oriented problem solving, these systems are quite similar but they can be also seen as complementary in the way they support learning tasks. While AIMS includes course representation and sequencing, TM4L is a kind of digital library, which does not include direct course representation.

### **Educational Standards for the Semantic Web**

The learning technology community is quickly adopting many of the Web technologies (XML, RDF(S), streaming video, etc.) (Devedzic, 2001). Simultaneously, the educational technology standardization is moving forward at rapid pace, with the IMS and the ADL having become the specification consortia that are tracked by vendors, implementers and academia. Both bring important contributions with respect to the management of

educational resources. There is a growing concern though towards the need of extending the existent educational standards, such as the IEEE/IMS LOM standard (<http://ltsc.ieee.org/wg12/>), in the context of the Semantic Web so as to allow improved semantic annotation of learning resources.

The emerging educational specification for learning content SCORM addresses semantic annotations, content aggregation and sequencing. However, SCORM (SCORM 1.3 specification [http://www.adlnet.org/screens/shares/dsp\\_displayfile.cfm?fileid=836](http://www.adlnet.org/screens/shares/dsp_displayfile.cfm?fileid=836)) has chosen its own XML formats and methodologies, thereby limiting the educational community to a restricted universe, and making it much more difficult to integrate E-learning with other business processes. It is thus recognized by some, including leaders of the SCORM development community, that there is a benefit in opening up to the larger (Semantic) Web community. By design, these technologies make it easier to integrate learning material with other material by avoiding cumbersome translations of existing vocabulary and semantic descriptions.

It is important to consider effective specification of sequencing and annotation of material on a semantic level. One step towards achieving this is proposed in (Aroyo et al., 2003) by mapping the sequencing in the current SCORM standards onto OWL and DAML-S (<http://www.daml.org/services/owl-s/>). Such a DAML-S translation can then be used to integrate SCORM based learning environments with other business processes or Web services that have a DAML-S description.

### **Semantic Web Educational Services**

In the current efforts targeting integration of various educational systems and content providers, Devedzic (Devedzic, 2003) proposes educational servers, which are based on using standards, ontologies, and pedagogical agents to support interaction between clients (authors and students) and servers (hosting educational content and services). He suggests that the interaction in the future educational systems will be between learners and services through educational service directories. While agreed with this vision, we believe that WBES interactions in the near to medium future will be between educational systems and/or their components, i.e. before achieving the large scale service-based integration, possible effective communications between systems and their components must be explored and exploited.

Another service-oriented perspective on the integration is given by the Elena project (Simon et al., 2003), which defines a smart learning space of educational service providers based on the Edutella (Nejdl et al., 2002) peer-to-peer framework for interoperability and resource ex-change between heterogeneous educational applications and different types of learning resource repositories. In the same context, we also see specific efforts trying to fill the gap between adaptive educational systems and dynamic learning repository networks, by proposing service-based architectures for personalized e-Learning. An example is the Personal Learning Assistant (Dolog et al., 2004), which uses Semantic Web technologies for realizing personalized learning support in distributed learning environments.

### **Modularized Adaptive WBES Architectures**

The analysis of many current adaptive concept-based WBES shows that they share common architecture features. This enables the specification of a common reference architecture for adaptive concept-based WBES, which will allow for a more structured and common approach in their comparison, evaluation and building.

If we consider the problem of efficient construction of adaptive concept-based WBES that complement (serve as advisors to) each other by sharing resources and components, the obvious answer is a modularized approach in building such systems. This implies a component-based architecture that allows sharing knowledge (e.g. domain ontologies, learning resources, course models, and user models) and components (e.g. user modeling, course sequencing, ontology visualization, keyword search).

We have proposed such a general reference architecture (Dicheva & Aroyo, 2004) addressing the following research questions:

1. Level of granularity of information exchange: what should be the information contained in one communication transaction? For example, in the second scenario, should the author be allowed to ask about importing the entire domain model of another system in one transaction?
2. Request semantics: What kinds of questions the requesting system should be able to ask?
3. Request syntax: In what a form the questions should be expressed?

4. Domain or user model awareness: Should the requesting system send any indication about what it “knows” or its user already “knows”, so that the responding system doesn’t send information already known? If so, what kind of information and in what a form?

With regard to the grain size of exchanged information, we consider two issues as important for the communication quality and efficiency between the systems, (1) conciseness of the request and the reply, and (2) completeness of the request and reply.

Concerning the “understanding” between each other, the systems must “know” the basic terms for structuring and using ontology-based learning resource repositories, such as ‘concept’, ‘relation/association’, ‘role in a relation’, ‘resource’, etc., which make the common ground for the semantic understanding. In other words, the different systems must know how to map their internal knowledge to the basic concepts of this common ground. This lightweight mapping process, as opposed to very expensive reasoning processes, is a key aspect of the proposed approach. In this context we also propose using XML-based protocols, so that any application can “understand” them. In relation to the domain and user awareness we propose that the systems share a common user model, possibly through using a user modeling service. In that case the responding system will not need to ask the requesting system what the user already knows. A common (shared) user model is only feasible if all WBES systems within the framework have concept-based representation of their subject domain.

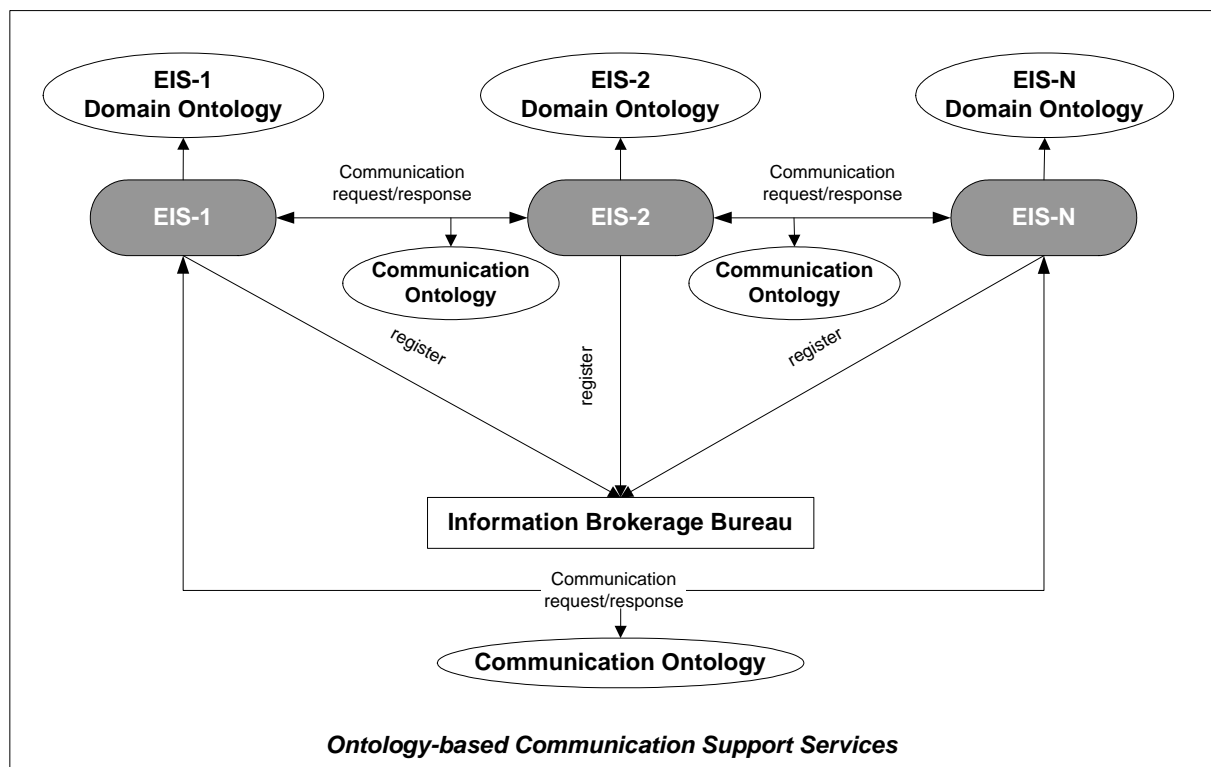


Figure 1. General architecture for component-based EIS interoperability

Thus, the proposed general architecture for supporting sharing and exchanging information between adaptive concept-based WBES include (Figure 1):

- Stand-alone, component-based independent WBES using their private subject domain ontologies.
- Information brokerage bureau where all applications are registered.
- Services to support systems communication, including ontology-related services, e.g. for ontology mapping.
- Communication bridges between the systems supporting standardized transport mechanisms and a common interaction protocol.

The communication between the systems requires not only standardized transport mechanisms and communication languages, but also common content languages and semantics. As to the communication semantics, in order for the applications to understand each other we propose using a communication ontology that defines the vocabulary of terms used in the messages at both message and content layers. To interpret the requests and answers standardized domain ontologies, UM ontologies, as well as up-per-level ontologies such as

WordNet (<http://www.cogsci.princeton.edu/~wn/>), SUMO (SUMO: Suggested Upper Merged Ontology <http://ontology.teknnowledge.com/>), etc. can be used.

## Authoring of Adaptive Concept-based WBES

Building adaptive concept-based WBES requires a lot of work and often is done from scratch. It becomes even more demanding with the constant increase of the information available on the Web and with the involvement of complex adaptation strategies for the instructional content presentation and navigation. A central problem in maintaining WBES popularity and benefiting from their wide use in practice is the fact that the current approaches for their building are rather inflexible and not efficient. The current way of designing such systems offers little space for reusing or sharing of content, knowledge and functional components. In addition, e-learning systems often lack a good authoring interface and require low-level programming skills from the content experts. The high and dynamic user demands in many aspects of software production are influencing research in the field of intelligent educational software as well (Major & Ainsworth, 1997). The ultimate problems are related to keeping up with the constant requirements for flexibility and adaptability of content and for reusability and sharing of learning objects and structures (Devedzic et al., 2000). Another problem in the current WBES research is that assessment of the existing systems is difficult as there is no common reference architecture, nor standardized approaches. Thus, there is an increasing need for efficient support environments for the designers and builders (authors) of adaptive WBES. We envisage that such support should include automatic or semi-automatic performance of some authoring activities, intelligent assistance to the authors in the form of hints, recommendations, templates based on recognizing different information patterns within subject domain content/ontologies or presentation (sequence) patterns, etc.

Considering the specification of modularized common reference architectures for WBES, the authoring of adaptive concept-based WBES should also be based on a strict separation and independency of the roles of the domain expert and the course author, which implies separate definitions of the domain knowledge (including also educational resources) and the instructional/course knowledge (including also the adaptation and personalization strategies) (Aroyo & Dicheva, 2004). We identify three groups of authoring activities: (1) authoring of the content, (2) authoring of the instruction process and (3) authoring of the adaptation and personalization. These authoring activities ensure structuring and editing of domain concepts and resources, modeling of the process of course task sequencing and choosing and applying an appropriate adaptation strategy.

A typical example of an authoring environment for an adaptive concept-based WBES is given by AIMS (Aroyo & Dicheva, 2002). Figure 2 shows the AIMS authoring environment, which supports the above groups of authoring activities via three tools that are typical for this class of systems: Domain Editing, Course Task Sequencing and Resource Management.

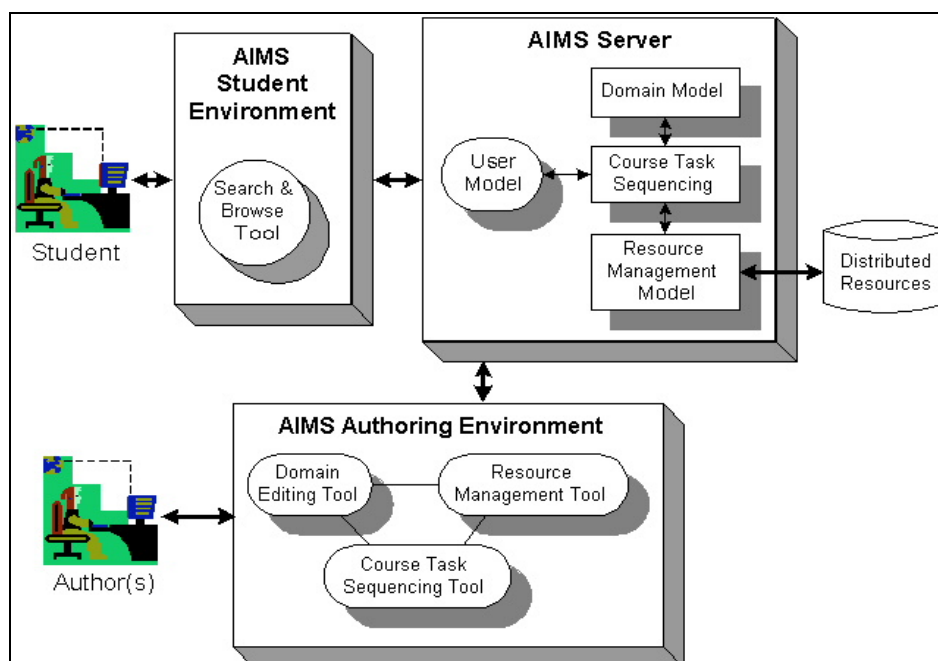


Figure 2. The global AIMS Architecture

The next three sub-sections illustrate the main aspects of authoring of educational content, instructional process and adaptation within the context of AIMS. Finally, in subsection “Process-aware Authoring Support for Adaptive WBES” we outline the main issues related to authoring tools employing the presented approach.

### **Authoring of Educational Content**

Content authoring in adaptive concept-based WBES concerns creation of learning objects and their annotation (e.g. creation of metadata, marking-up), and involves creation of links (conceptual and functional) between those learning objects. At this level the authors perform domain-related and resource-related authoring activities.

Domain-related authoring activities: Constructing (editing and annotating) the do-main model in terms of concepts and links (from an externally or internally created subject domain ontology, a common vocabulary of terms describing the basic knowledge about the selected subject domain). A domain concept is defined as a pair consisting of the name of the concept and the corresponding set of attributes. A link de-fines an association between two concepts of a certain type with a given weight and in a specified link direction.

Resource-related authoring activities: Building a collection of educational re-sources in the resource library model (e.g. inserting new learning resources or editing existing resources in the resource repository). Each resource is enriched with the appropriate AIMS metadata to facilitate its further use within the course-sequencing module. (The metadata in AIMS is LOM-based (LOM IEEE P1484.12 Learning Object Metadata Working Group), which is an illustration of the use of standards-based data in these systems.). An interesting issue in the task-based WBES is the explicit attention to the resources. As opposed to conventional educational adaptive hypermedia systems, these systems usually maintain a clear separation between concepts and resources. First of all, this means that the handcrafting nature of adaptive hypermedia systems is out of the question, and that the application designer has to specify the design first at the level of abstract concepts, leaving their implementation by resources separate. At the same time, this allows later an extra dimension of adaptation, as the definition of the associations of resources and concepts can be programmed in such a way so as to realize personalization and adaptation.

Central to this separation of resources and concepts is the notion of conceptualization. The role of concept structures is to describe the content at the level of abstract concepts, but it is also a way to deal with the resource-concept separation. In educational applications it is common to reuse and exchange resources between applications, which means that learning objects are used in different course applications. To facilitate this, it pays off to base the conceptual structures on standardized metadata, so that the systems can easily offer different kinds of adaptation and personalization on a shared set of learning resources.

### **Authoring of Instructional Process**

Authoring of the instructional process in concept-based WBES typically involves course construction activities, which include generating a course tasks model to represent a course structure and to serve as a basis for the further sequencing of course tasks. In order to produce an instructional task sequence the author usually (1) selects concepts from the domain model and assigns them to course topics; (2) selects specific sequences of course topics realizing the learning goals; and (3) assigns course tasks for each topic (each task will cover more than one learning activity).

### **Authoring of the Adaptation and Personalization**

The authoring of adaptation considers user-related authoring activities that deal with the definition of user model attributes and their application in the adaptation and the course task sequencing (Dicheva et al., 2003). At this stage the authors typically define and apply various adaptation strategies in order to achieve the most efficient tailoring of the learning content to the individual learners.

In educational adaptive hypermedia systems, for instance, the adaptation primarily concentrates on the navigation structure and the construction of links and content in such a way that the presentation is adapted to the user. Even in the more general class of adaptive Web information systems the focus on navigation engineering is relatively high. In the adaptive task-based WBES the adaptation is styled quite differently, as the personalization is mainly constructed via the identification of tasks and the subsequent instructional sequencing.

## Process-aware Authoring Support for Adaptive WBES

After discussing the different authoring activities we now turn to the authoring support tools. Many researchers in the field of educational systems have been focusing lately on authoring systems and their improvement (Kiyamaet al., 1997; Vassileva, 1995). Although the research field has already identified the main requirements for WBES authoring, still only very application dependant authoring systems exist and these do not focus neither on the reusability of the development efforts, nor on the applicability in different domains (Murray, 1999). As the application domains are multiple and serve various needs, the benefit of a common reference architecture would be significant.

The authoring approach that we present here in short, was introduced by (Aroyo & Dicheva, 2004) and further elaborated by (Aroyo et al., 2004). It focuses on the authoring at three levels of abstraction: (1) conceptual level, (2) application level, and (3) presentation level. It takes an onto-logical approach towards specifying the activities involved in application authoring. This means that a formal specification of the application authoring process is obtained, based on a definition of an authoring task ontology that captures in a task-oriented fashion the engineering activities involved in the application development, their requirements, constraints and results. An ontology-based representation of the application authoring process is a semantically enriched conceptual structure that can be used to support application authors. Figure 3 represents the architecture for the ontology-based authoring support realized by two modules, an operational module and an author-assisting module. The former is responsible for implementing the set of authoring tasks, while the latter is responsible for the immediate interaction with the author and for providing the actual support in the process of application authoring. In the case of educational applications, the operational module handles basic courseware authoring tasks related to information manipulation, consistency and possibly cooperation. It enables the process of domain creation, course structure building and educational resource management. The assisting module interprets the results of the op-erational module processing and gives hints to the author of how to edit the domain, how to create a course structure, how to link documents to the domain ontology or to course items, etc.

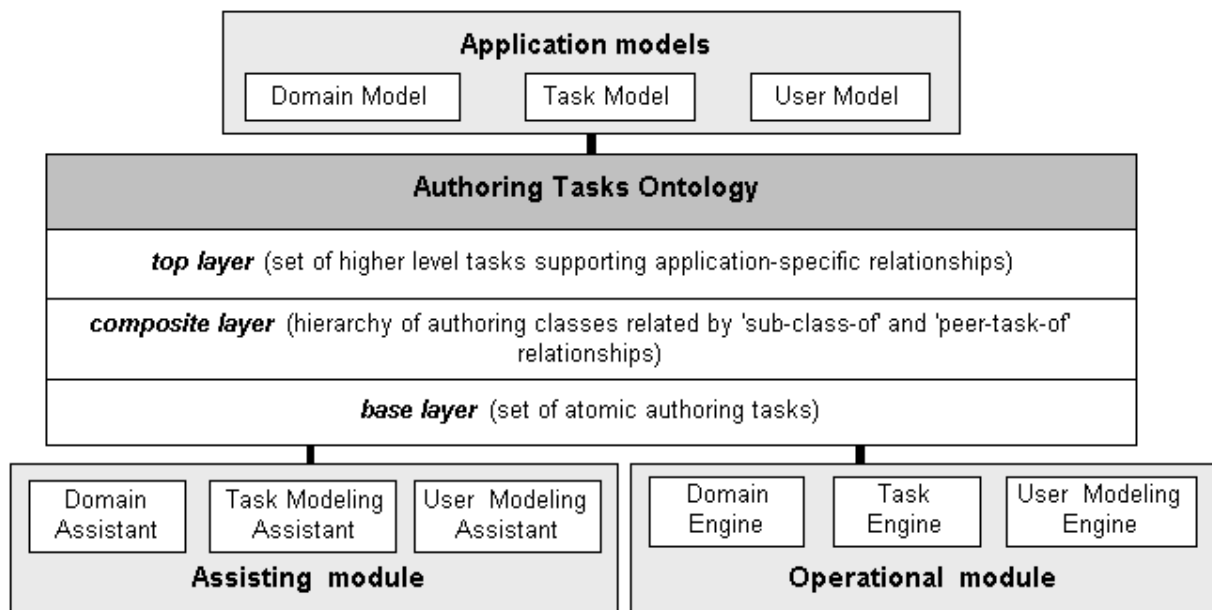


Figure 3. AWBES authoring support based on authoring tasks ontology

The design of the authoring task ontology involves three main layers (see Figure 3):

- A base layer with set of atomic authoring tasks (primitive functions).
- A composition layer including a hierarchy of authoring task classes that represent conceptual categories of relationships (interdependence) between primitive functions.
- A top layer including a set of higher level authoring tasks supporting application-specific relationships.

The atomic authoring tasks are primitive functional concepts, which are basic for the understanding and performing of the concept-based authoring process, and allow to build an ontology vocabulary. The primitive functions are defined on objects (e.g. concepts, links) within a specific concept-based structure (e.g. domain model). They express a simple functional formalism, where the object changes the structure, or the structure is manipulated. Examples of atomic authoring tasks include: Create (Structure), Create (Object), Add (Object,

Structure), Delete (Object, Structure), Edit (Object, Structure), Link (Object1, Object2, Structure), etc. Note that such task definitions are independent of the information structure - the only prerequisite for the structure is to be concept-based.

In the composite layer there is a hierarchy of authoring classes related by 'sub-task-of' and 'peer-task-of' relationships: 'sub-task-of' represents (part-of) specialization between two tasks, while 'peer-task-of' relationships are viewed as a referral (is-a) mechanism to other authoring classes, which are considered as peers related to different contexts. These links can be weighted to represent the degree of relevancy as a peer. These relationships present certain aggregation criteria that are used for functional grouping primitive functional concepts (atomic authoring tasks) into higher-level authoring tasks (classes).

In the top layer, there is a set of application-related higher-level tasks to represent categories of application-specific relationships (including causal and other relations among authoring tasks). These relationships are not concerned with specific changes in the objects (concepts, links, resources), but represent specific functions in the concept based authoring process. The relationships may also represent the role (application dependent) of one authoring task for another authoring task. Examples are 'precedence' to represent a temporal relationship between two tasks, 'prerequisite' to represent a causal relationship between two tasks, or 'is-assigned-to', 'is-achieved-by', and 'is-delegated-to' to represent task-agent relationships.

To extract additional semantics for the authoring process from the authoring task ontology, there will be rules to query the ontology and find patterns and alternatives in the navigation within the network of authoring tasks. This can facilitate the work of authors aiming at a specific task. This would require a rule-based model over the schematic representation of the ontology to support the interpretation of its scheme and allow for extracting additional semantics that can be applied in the reasoning strategies of the authoring support tools. The rules will assign interpretations directly to the authoring task ontology graph (based on the RDF syntax), while the vocabulary of the graph is determined by the set of primitive functional concepts within the base layer.

## Conclusions

To conclude, in the field of (A)WBES, it is clearly a transition stage, where the information is reaching critical amounts, the user demands for more personalized and adaptive system interaction are constantly rising, and the Web technologies are racing the clock to conquer new horizons. In this context, semantics plays a central role. It has become more explicit and this steadily changes the way in which we deal with information. Dealing with ontologies and concepts increases our conceptual awareness and influences the style of information perception, which reflects in the demands for using and authoring (A)WBES. The strive towards machine-readable semantics, on the one hand allows systems to more easily reach a conceptual agreement and exchange information and functional components. On the other hand, it provokes a 'greediness' to have more and more intelligence in the user-system interaction. With the new frame-works and architectures that are evolving in order to meet the semantic challenge the goal has become to provide the users (both students and authors) with a seamless personalized interaction with the WBES. It is unfeasible to predict, in the longer term, where e-Learning is going to go and what will be the new challenges then, but for now it is unambiguous that the current vision of the Educational Semantic Web propagates interoperability, reusability and shareability, all grounded over an extensive expression of semantics with a standardized communication among modular and service-oriented systems. An essential element for success is the availability of support for user-friendly, structured and automated authoring of educational systems, where it is important to find the balance between, on the one hand, exploiting explicit semantic information for agreement and exchange of educational information, and on the other hand, collecting and maintaining that information semantics.

## References

- Anderson, T., & Whitelock, D. (2004). The Educational Semantic Web: Visioning and Practicing the Future of Education. *Journal of Interactive Media in Education*, retrieved October 4, 2004, from <http://www-jime.open.ac.uk/2004/1>.
- Aroyo, L., & Dicheva, D. (2001). AIMS: Learning and Teaching Support for WWW-based Education. *International Journal for Continuing Engineering Education and Life-long Learning*, 11 (1/2), 152-164.

- Aroyo, L., & Dicheva, D. (2002). Courseware Authoring Tasks Ontology. In Kinshuk, R. Lewis, K. Akahori, R. Kemp, T. Okamoto, L. Henderson & C.-H. Lee (Eds.) *Proceedings of the International Conference on Computers in Education*, Los Alamitos, CA: IEEE Computer Society, 1319-1321.
- Aroyo, L., & Dicheva, D. (2004). Authoring Support in Concept-based Web Information Systems for Educational Applications. *International Journal of Continuous Engineering Education and Life-long Learning*, 14 (3), 297-312.
- Aroyo, L., Inaba, A., Soldatova, L., & Mizoguchi, R. (2004). EASE: Evolutional Authoring Support Environment. In J. C. Lester, R. M. Vicari, F. Paraguaçu (Eds.) *Proceedings of the ITS'04 Conference*, Berlin: Springer Verlag, 140-149.
- Aroyo, L., Pokraev, S., & Brussee, R. (2003). Preparing SCORM for the Semantic Web. *Paper presented at the International Conference on Ontologies, Databases and Applications of Semantics (ODBASE'03)*, 3-7 November, Catania, Sicily.
- Bourdeau, J., & Mizoguchi, R. (2002). Collaborative Ontological Engineering of Instructional Design Knowledge for an ITS Authoring Environment. *Paper presented at the ITS 2002*, June 2-8, 2002, Biarritz, France.
- Breuker, J., & Bredeweg, B. (1999). Ontological Modeling for Designing Educational Systems, *Paper presented at the Workshop on Ontologies for IES at AIED'99*, 19-23 July, Le Mans, France.
- Brusilovsky, P. (2004). KnowledgeTree: A Distributed Architecture for Adaptive E-Learning. In *Proceedings of the Thirteenth International World Wide Web Conference (WWW 2004)*, New York: ACM Press, 104-113.
- Brusilovsky, P., Eklund, J., & Schwarz, E. (1998). Web-based education for all: A tool for developing adaptive courseware. *Computer Networks and ISDN Systems*, 30 (1-7), 291-300.
- Brusilovsky, P., Schwartz, E., & Weber, G. (1996). ELM-ART: An Intelligent Tutoring System on the World Wide Web. *Paper presented at the Third International Conference on Intelligent Tutoring Systems (ITS'96)*, 12-14 June, Montreal, Canada.
- Chen, W., Hayashi, Y., Kin, L., Ikeda, M., & Mizoguchi, R. (1998) Ontological Issues in an Intelligent Authoring Tool. In Chan T-W., Collins A. & Lin J. (Eds.) *Proceedings of the ICCE'98 Conference*, Norfolk, VA: AACE, 41-50.
- de Bra, P., Aerts, A., Berden, B., de Lange, B., Rousseau, B., Santic, T., Smits, D., & Stash, N. (2003). AHA! The Adaptive Hypermedia Architecture. *Proceedings of the fourteenth ACM Conference on Hypertext and Hypermedia*, New York: ACM Press, 81-85.
- Devedzic, V., Jerinic, L., & Radovic, D. (2000). The GET-BITS Model of Intelligent Tutoring Systems. *Journal of Interactive Learning Research*, 11 (3), 411-434.
- Devedzic, V. (2001). The Semantic Web - Implications for Teaching and Learning, In C. H. Lee, S. Lajoie, R. Mizoguchi, Y D. Yoo & B. du Boulay (Eds.) *Enhancement of Quality Learning Through Information & Communication Technology (ICT)*, *Proceedings of ICCE/SchoolNet 2001 Conference*, Korea: Incheon National University of Education, 29-30.
- Devedzic, V. (2003). Next-generation Web-based Education. *International Journal for Continuing Engineering Education and Life-long Learning*, 11 (1/2), 232-247.
- Dicheva, D., Aroyo, L., & Cristea, A. (2003). Cooperative Courseware-Authoring Support. *International Journal of Computers and Applications*, 25 (3), 179-187.
- Dicheva, D., & Aroyo, L. (2004). General Architecture Supporting Component-based EIS Interoperability. *Paper presented at the Workshop on Semantic Web Technologies for E-Learning, ITS'04*, 30 August – 3 September, Maceiò, Brazil.

- Dicheva, D., Dichev, C., Sun, Y., & Nao, S. (2004). Authoring Topic Maps-based Digital Course Libraries, *Paper presented at the Workshop on Applications of Semantic Web Technologies for Educational AH, in conjunction with AH'04*, 23-26 August, Eindhoven, The Netherlands.
- Dolog, P., Henze, N., Nejd, W., & Sintek, M. (2004). Personalization in Distributed eLearning Environments. *Proceedings of the International WWW'04 Conference*, New York: ACM Press, 170-179.
- Ikeda, M., Seta, K., & Mizoguchi, R. (1997). Task Ontology Makes It Easier To Use Authoring Tools. *Paper presented at the Fifteenth International Joint Conference on Artificial Intelligence (IJCAI'97)*, 23-29 August, Nagoya, Japan.
- Kiyama, M., Ishiuchi, S., Ikeda, K., Tsujimoto, M., & Fukuhara, Y. (1997). Authoring Methods for the Web-Based Intelligent CAI System CALAT and Its Application to Telecommunications Service. *Paper presented at the AAAI-97: Conference of the American Association for Artificial Intelligence*, 27-31 July, Providence, USA.
- Major, N., & Ainsworth, S. (1997). Developing Intelligent Tutoring Systems Using a Psychologically Motivated Authoring Environment. *Proceedings of the AAAI Fall Symposium, (FS-97-01)*, 53-59, AAAI Press, Cambridge, MA.
- Mizoguchi, R., & Bourdeau, J. (2000). Using Ontological Engineering to Overcome Common AI-ED Problems. *International Journal of Artificial Intelligence in Education*, 11 (2), 107-121.
- Murray, T. (1999). Authoring Intelligent Tutoring Systems: An analysis of the state of the art. *International Journal of Artificial Intelligence in Education*, 10, 98-129.
- Nejd, W., Wolf, B., & QuLearning, C. (2002). EDUTELLA: A P2P Networking Infra-structure Based on RDF. *Paper presented at the 11th International WWW'02 Conference*, retrieved October 13, 2004, from [http://www.kbs.uni-hannover.de/Arbeiten/Publikationen/2003/edutella\\_cn03\\_submission.pdf](http://www.kbs.uni-hannover.de/Arbeiten/Publikationen/2003/edutella_cn03_submission.pdf).
- Ritter, S. (1997). PAT Online: A Model-Tracing Tutor on the World-Wide Web. *Paper presented at the Workshop on Intelligent Educational Systems on the WWW*, 18-22 August, Kobe Japan.
- Simon, B., Nejd, W., Miklos, Z., Sintek, M., & Salvachua, J. (2003). Elena: A Mediation Infrastructure for Educational Services. *Paper presented at the 12th International WWW'03 Conference*, Retrieved October 13, 2004, from <http://www2003.org/cdrom/papers/alternate/P616/p616-simon.html>.
- Stutt, A., & Motta, E. (2004). Semantic Learning Webs. *Journal of Interactive Media in Education*, 2004 (10), retrieved October 4, 2004, from <http://www-jime.open.ac.uk/2004/10>.
- Vasilakos, A., Devedzic, V., Kinshuk, & Pedrycz, W. (in press). CI in Web-based Education: A Tutorial. *Journal of Interactive Research on Learning*.
- Vassileva, J. (1995). Dynamic Courseware Generation: at the Cross Point of CAL, ITS and Authoring. *Paper presented at the International Conference on Computers in Education*, 5-8 December, Singapore.
- Weber, G., Kuhl, H.-C., & Weibelzahl, S. (2001). Developing adaptive Internet-based courses with the authoring system NetCoach. *Lecture Notes in Computer Science, LNAI 2266*, 226-238.