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CONTEXTUALIZED MODELS AND METADATA FOR  
LEARNING REPOSITORIES

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## Contextualized Models and Metadata for Learning Repositories

Open Learning Repositories (OLR for short) are metadata-based course portals, which structure and connect modularised course materials distributed all over the Web. The modular content is integrated by explicit metadata information in order to build courses and connected sets of learning materials. Modular content can be reused for other courses and in other contexts, leading to a course portal, which integrates LOs from different sources and authors. The system houses a relational database to store all metadata. The database does not store content, but references it by URLs. The OLR system at the time of writing houses two courses, one in Artificial Intelligence and one in Software Engineering.

The focus in the first and second generation of Open Learning Repositories (Dhraief, Nejdil, Wolf, & Wolpers, 2001) was the technical infrastructure. The main questions were, how to store the metadata, whether to use O-Telos (Mylopoulos, Borgida, Jarke, & Koubarakis, 1990), XML or RDF (World Wide Web Consortium, 1999) etc. However, there was a lack of pedagogical background in the first and second generation of OLRs. Therefore it was decided to design and implement a new generation of OLR, which designated as “OLR3”. This Learning Repository is open to different pedagogical approaches, which can be implemented explicitly. This means that different views on LOs and different learning strategies, guided by both instructional as well as situated approaches can be implemented. The system extended the LO Metadata Standard LOM (IEEE Learning Technology Standards Committee, 2002) to incorporate a strong focus on pedagogical approaches.

The results of an evaluation of the second generation of the Open Learning Repository revealed that the system did not meet the students’ needs. Therefore in the design of OLR3 the investigators addressed the entire educational setting, which is supported by technology instead

of focussing on the technology in an isolated way. For this, a scenario-based approach was developed to guide the design process of OLR3 in order to address both the technology as well as the educational setting. The design of the educational setting influences the use of an e-learning system. The multi-disciplinarity of the project team required a medium for communication that allows the communication of ideas and theories beyond the different areas of expertise. The scenario-based approach (Carroll, 2000) helped to handle this task.

#### Different Views on LOs: Models in the OLR3

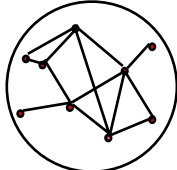
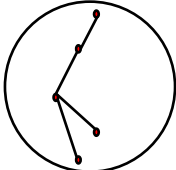
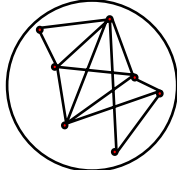
Within the OLR3 users, such as life long learners, can choose their preferred learning strategy. The OLR3 contextualizes learning objects (LOs), offering several contexts to the user rather than just one. Each context is designed according to a specific pedagogical approach. From a pedagogical point of view these approaches can be very diverse. They can be derived from different learning paradigms and principles, such as situated learning based on theories of situated cognition and instructional models based on information processing theories. While some models focus on distributing domain specific knowledge to individual users, others focus on co-construction of knowledge by learning communities. Some models focus on developing competencies, such as coordinating team work, managing projects or conducting scientific work. Each of these learning models are based on different approaches, but with several choices, learners, teachers or tutors might be able to choose the most suitable learning model and learning/teaching strategy for their particular needs.

In a life long learning context, learners should be able to decide on learning needs themselves and should be given a choice of their preferred way of learning. This requires reflection on one's own strategies of learning and teaching. Rautenstrauch (2001) explains: "Life-long learning will be a learners own decision (...) the learner is mature (...) he will identify

and define his own needs and preferred ways of learning (...) he will learn to learn self-organized, self-determined, and independent from predetermined curricula and institutional forms of organization” (p. 6).

Therefore the Open Learning Repository (OLR3) was designed to be open to different learning and teaching strategies. In order to be able to implement diverse learning models the different metadata-models were separated: the *Domain Model*, the *Instructional Model* and the *Structural Model*

**Table 1:** *Domain Model, Instructional Model, and Structural Model.*

 <p><b>Domain Model</b></p>	 <p><b>Instructional Model</b></p>	 <p><b>Structural Model</b></p>
<p>Domain specific ontologies (MatterOfFactRelations, Meder, 2000). Structuring subject specific knowledge, skills, and competencies.</p>	<p>Instructional relations derived from different pedagogical approaches and learning models. Structuring learning processes and processes of cooperation in phases to guide learners and learning groups, and to support different learning strategies.</p>	<p>Relations (e.g. theory is generalizing example) are derived from different learning theories (cognitive science). The ontology of knowledge-types is taken from Meder (2000). Within OLR3 relations (called <i>take-offs</i>) support exploration.</p>

Specifying different metadata-models in the OLR3 is a means of representing different views on LOs. In the OLR there are three models to specify different aspects/views: *Domain Model*, *Instructional Model*, and *Structural Model*. These different models can be structured by different experts in the different fields (experts in the subject domain may structure the *Domain Model* whereas instructional designers may extend the *Instructional Model*).

### *Domain Model*

In the *Domain Model* domain and subject specific ontologies are specified, mainly including MatterOfFactRelations, both hierarchical and associative (Meder, 2000). This knowledge space includes conceptualization of subject specific knowledge, skills and competencies.

### *Instructional Model*

As mentioned above, pedagogical models are diverse. Nevertheless most of these models have one thing in common: they structure learning processes in phases. Within the OLR3 these phases form guiding sequences – learners are guided through learning processes or processes of cooperation.

There is no unique ontology for learning but different views, approaches, theories and models. In the Instructional Model learning phases and learning processes are specified. They are derived from different learning models and learning theories, such as Problem-Based Learning, Case-Based Learning, Expository Learning, Communities of Practice, etc. As the investigators tried to represent these aspects in LO metadata, it was realized that existing metadata standards do not address learning processes (Allert, Dhraief, & Nejdli, 2002), an issue also discussed by Meder (2000), who stresses, that LOs should be defined in six dimensions, where one of these dimensions defines the position of an LO within the process of knowledge acquisition: “A LO must be defined in the dimension of logic-operative modes of processes, i.e., there are methods which determine the process of acquisition of knowledge”. [Ein didaktisches Objekt muss bestimmt sein (...) in der Dimension logisch-operativer Verlaufsformen, d.h. es gibt Methoden – im definierten Sinne – die den Verlauf der Aneignung von Wissen bestimmen können] (Meder, 2000, p. 403).

The Instructional Model defines learning phases and presents them as guiding structures (learning sequence) to the learners. Here are exemplified two different models which have been implemented so far:

1. Expository Learning by Ausubel (1968).
2. A process-oriented model called “Trails of Competence”. The design of this model was guided by the principles of situated learning and the concept of Communities of Practice. Next to subject-specific learning objectives, learners also study how to conduct scientific work or how to manage a project. The phases are structured according to activity theory (Oesterreich, 1981; Volpert, 1999).

**Table 2:** Phases modelled in OLR3 (Relations between them are „followed by“)

Phases modelled along the model of Expository Learning by Ausubel (1968)	Phases modelled along the activity-theory (Oesterreich, 1981; Volpert, 1999)
Orientation (Advance Organizer)	Ask Questions
Conceptualization (Progressive Differentiation)	Plan Proceeding
Practice	Apply Plan
Integrating and Connecting	Analyse
	Interpret and Discuss

These different sequences, specified in the *Instructional Model*, serve as navigational threads and address the problem of linking de-contextualized objects to stringent learning sequences and coherent structures. The defined structures work as guidance to authors presenting learning material as well as to students navigating through the material. The process-oriented model also facilitates students in coordinating their project and their cooperation with peers.

### *Structural Model*

By separating the *Instructional Model* from the *Structural Model*, one can model guiding as well as explorative structures. Whereas in the *Instructional Model* learning processes are specified in order to support guidance, in the *Structural Model* knowledge types and relations are specified in order to support exploration and elaboration. Course authors may also use the relations to integrate further material and LOs, beyond the guiding sequence. Here are some examples of knowledge types and relations:

- Theory generalizes example.
- Exercise applies theory
- Is similar to
- Is different from
- Is prerequisite for

**Table 3:** *Methodical Relations specified in the Structural Model, expressed as Triple*

<b>Entity</b>	<b>Relation</b>	<b>Entity</b>
LO (theory)	generalizes	LO (example)
LO (exercise)	applies	LO (theory)
LO	is similar to	LO
LO	is different from	LO
LO	is prerequisite for	LO

In order to model these relations, each LO must be categorized with regard to its knowledge-type. The ontology of knowledge-types is taken from Meder (2000). Based on these models the interface of the OLR3 looks as shown in Fig. 1.

#### Contextualizing LOs: Diverse Learning Models

The use of LOs within the OLR3 depends on the learning model which guides the design of the learning sequence. A LO can fill various roles within different learning sequences. For instance a text or video-file can be used in the phase called “Advance Organizer” (Expository Learning) as

well as in the phase “Apply Plan” (Trails of Competence). The concept of Role-Based Metadata, which specifies static as well as dynamic metadata was proposed. (Allert et al., 2002).

### *Expository Learning in OLR3*

According to the model of Expository Learning by Ausubel (1968), learning proceeds through four phases. Within the OLR3 LOs which serve the specific instructional purpose of a phase are presented to the user.

**Table 4:** *Phases of Expository Teaching according to Ausubel (1968)*

Phase	Instructional purpose
Orientation (Advance Organizer)	Prepare for integration of new knowledge. Subsuming bridge between new learning material and existing related ideas. Present introductory material that helps students relate new information to existing knowledge schemes. New ideas and concepts must be "potentially meaningful" to the learner. Help to relate new ideas to existing scheme. Ask questions like: What do you want to find out? What operations do you need to perform to get there? What do you already know?
Conceptualization (Progressive Differentiation)	The most general ideas of a subject should be presented first and then progressively differentiated in terms of detail and specifics. Organize new material by subordination, superordination and coordination.
Practice	Practice and apply.
Integration and Connection	Integrate and link new knowledge to other fields of knowledge and context areas as well as to the Advance Organizer. Instructional materials should attempt to integrate new material with previously presented information through comparisons and cross-referencing of new and old ideas.

This learning theory concentrates on distributing knowledge in a structured way. To guide learners, the phases form a path-like navigation structure on the interface. To support exploration, related LO are presented via links called “take-offs”. According to Ausubel relations such as “is similar to” and “is different from” support learning. Furthermore, the interface provides functions like “add comment”, “add bookmark”, “add keyword to metadata”.

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*Figure 1: Screenshot of interface “Expository Learning”*

### *Trails of Competence*

This process-oriented model focuses on competences. The core idea of this model is well described by Seufert, Lechner & Stanoevska (2002): “The goal in education is to teach knowledge not additively, but inter-linked by means of questions arising from business practice and scientific research. Only such inter-linked knowledge can be consciously disposed of in concrete situations. The quantity of information and the speed information gets outdated demands that formative, open-up knowledge be taught which enables learners to apply knowledge creatively to problem-solving, and, gives them the opportunity to create new knowledge (Nonaka & Takeuchi, 1995). The linkage of factual knowledge and creative problem solving techniques may constitute such formative open-up knowledge” (p. 44).

Investigators identified two major competencies:

- The competence to manage and coordinate project-oriented teamwork.
- The competence to plan and conduct scientific work.

Both of these competences are relevant in students further academic as well as professional careers. Phases were identified, which are relevant in both scientific work and project management: From the point of view of psychology both of these processes can be characterised as intentional and goal-oriented activities. Therefore these activities were then structured according to activity theory (Miller, Galanter, & Pribram, 1960 and Oesterreich, 1981) and

organized into phases. The phases are meant to provide orientation, structure student activities, and guide navigation.

Reflecting the author's concept, it was realised that universally valid concepts of scientific work cannot be discerned. At this point investigators decided on the principle of Communities of Practice, that both research methods and scientific communities are diverse (heuristic, empiric as well as hermeneutic among others). There are communities focussing on multidisciplinary topics such as technology & education. For example there are communities such as *Semantic Web*, *Digital Libraries*, *Peer to Peer*, *Robotics*, *Adaptive Hypermedia*, *Media Education (a very local community within Germany)*, *Molecular Bioinformatics*, *Paleo Anthropology* etc. Any of these communities share different routines, rules, and procedures such as where and how (and how often) to publish results and share ideas (conferences, scientific magazines, or books (within month or years)); where and how to meet and communicate (at local workshops or at international conferences) e.g.

Lave & Wenger (2001) view learning as situated activity. Its central characteristic is a process that they call *legitimate peripheral participation*. Learning means to allow students to move from peripheral participation to full membership. Scientists for example are full members or participants of the core group within a specific scientific community. Therefore, within the OLR3, members of specific communities (experts) explain their strategies of scientific work: how they state the state-of-the-art and identify relevant research questions; how they conduct research; and how they publish. They give examples of their own research work, point out relevant conferences, mailinglists, and papers. Within each phase, experts also provide LOs which are relevant to understanding the research topic. To support reflection on learning experts also asked to state criteria of what they think is "a good research question" etc.

As several experts were asked to draft their strategies and provide LOs within the OLR3 students may compare different strategies, procedures and routines within different scientific communities. Students and student groups are enabled to identify their topics of interest and choose their favourite experts in order to ask them for support and consult them and their work. Students then form instances of expertise-trails in order to share their work and learning progress. They search for LOs on the web, collect and provide LOs themselves, write reports and present their own ideas and strategies. Experts (full members of communities) communicate with students.

These competence-based trails are called ScieCom: *Introduction to Scientific Communities* (See <<http://www.learninglab.de/~allert/olr/studie4/site/index.htm>>).

For the project-based expert-trails investigators consulted experts, who actually manage projects.

Scenshot will be intergrated

**Figure 2:** Screenshot of 'Trails of Competence' (*Introduction to Scientific Communities*)

The finished system is planned to provide a library, which will provide collections of expert-trails and finished students work. Creating a new course means sampling relevant trails and entities.

A group of students used the 'Trails of Competence' OLR3 in the summer semester of 2003. They were asked to affirm the state-of-the-art and identify relevant research questions. They shared their work, provided documents, and described their strategies.

At first, the focus of this research was on designing, using and evaluating the "Trails of Competence" as soon as possible. Therefore, the complete metadata-based architecture was not

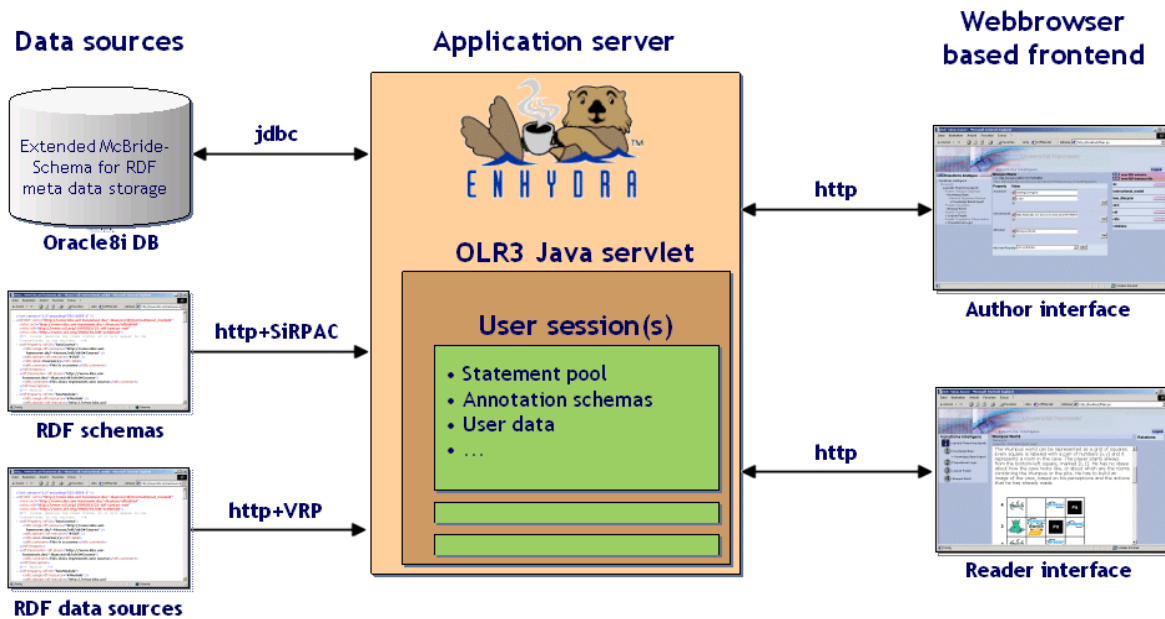
implemented, but a functional mock-up was built. This prototype, that is able to simulate the intended functionality, allowed investigators to rapidly use and evaluate the ‘Trails of Competence’. Use-cases were drafted and UML diagrams (Unified Modelling Language) were prepared. The interface was designed, and HTML pages were built and integrated with a basic workspace (BSCW, 1995-2001) in order to enable and support cooperative activities. Currently, this learning concept has been integrated into the metadata-based architecture.

### Architecture and Technology

The 3<sup>rd</sup> generation of the Open Learning Repository, OLR3, is implemented in Java and works as a JavaServlet, running on an open source Enhydra Application Server (Madl et al., 2002). It is connected to an Oracle Database via JDBC, which is used to store the metadata entered by course authors and students. There are two types of metadata: structured-metadata and annotated-metadata. The structured metadata represent information about the structure of a given course or course unit, the navigation path within this course or course unit, and the relations between different LOs. Annotated metadata represent the information about the content itself. A subset of the LOM metadata standard has been implemented to annotate the LOs. All metadata are represented in RDF and RDFS (World Wide Web Consortium, 2002). The RDF schemes, needed for either the annotation or the structure of learning, can reside anywhere on the Web, as do the LOs. The database only holds the metadata, and assembles courses from these records.

The system works on a “StatementPool”, which holds all metadata known to the system at runtime, relevant for a given course. When an author starts working on a course, the pool is filled with the already existing data about that course from the database, and all statements from the used RDF schemes. Any referenced RDF schema will be parsed using the SiRPAC RDF parser

(Melnik, 2001), whereas imported RDF files are parsed by a VRP RDF parser (Tolle, 2001), which provides semantic checks against given RDF schema rules.



**Figure 3: OLR Architecture**

### *Web Interface*

OLR3 provides a web-browser based metadata editor/viewer and two major user interfaces. The first one is used for readers preferring a more graphically oriented view and only minor functions for manipulation of the underlying metadata. The second one is designed for authors to provide a schema-driven and browser-based metadata editor with flexible binding to different RDF schemes.

*The Learner Web Interface:* A specific engine prepares and filters the content, and displays it based on a stored layout. The reader interface also offers the reader the possibility of making minor additions to the metadata of a selected course element by providing functions like “add comment”, “add bookmark”, “add keyword to metadata” etc. All those additions can be made private or public to other course readers.

The *Author Web Interface*: The second interface provides the actual metadata editor, which is intended for course authors, who can navigate through the structure tree of a course and select any sub-element. All existing editable metadata for this element are shown in the center of the screen, and the user can choose from a set of existing RDF properties, to add to the metadata, or to modify the existing data. The author can also bind RDF schemes (e.g., DC, DCQ, LOM) stored on the Web to extend the set of available properties for annotation, or unbind RDF schemes, that are not needed anymore. A “toolbar” holds those bound RDF schemes and offers the possibility of navigating through their structure by displaying an expandable tree view of any available property.

### Conclusion

Computer-Supported Learning intends to design an entire educational setting which is supported by technology. Life-long learners have to reflect their own learning needs in both form and content. Within OLR3 learners as well as teachers can choose a preferred learning concept. The design of the OLR3 was guided by a scenario-based design approach and the evaluation of a former version of OLR (OLR2). Designers and implementers were asked to write “scenarios-of-*intended-use*” whereas students were asked to write “scenarios-of-*actual-use*” at the end of winter semester 2002. In comparing these scenarios the design team realized that some functionalities provided by OLR2 (such as “add public comment”, “add URL”) have not been used by students. An analyses of the entire educational setting revealed, that cooperation among students which is enabled by technology did not take place as the educational setting itself did not support cooperation.

Therefore, in sommer semester 2003 the entire educational setting of the course was re-designed and supported by OLR3. Learning objectives of the course comprised domain specific knowledge as well as the competencies of scientific work.

Diverse metadata schemes and ontologies have been developed within different projects. The German Institute of Standardization (DIN), Workinggroup DIN-EBN Didactics, compares and integrates different approaches taking into account both national and international concepts, standards, and specifications. Projects may not re-invent the wheel but use existing ontologies. In the further development of OLR3 designers and implementers will also take into account existing ontologies and concepts.

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## Appendices

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## Figure Captions

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