

TECHNICAL UNIVERSITY OF CRETE

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A Framework and an Architecture for Supporting eLearning Applications on top of Multimedia Digital Libraries

**A dissertation submitted for the degree
of Master of Science in Computer Engineering**

by

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Abstract

One of the most important applications of libraries is learning. eLearning applications are immensely more valuable when they can use the wealth of information that exists in Digital Libraries. However, Digital Libraries and their standards developed independently from eLearning applications and their standards, presenting interoperability issues between digital libraries and eLearning applications. This is a complex and multilevel problem. It is crucial to bridge the interoperability gap between digital libraries and eLearning applications in order to enable the construction of eLearning applications that easily exploit digital library contents.

This thesis proposes a generic interoperability/repurposing framework implemented in a service-oriented architecture to support the construction of eLearning applications on top of Digital Libraries, focusing on multimedia Digital Libraries. This Architecture Supports Interoperability between Digital Libraries and ELearning applications (ASIDE) in a dynamic eLearning environment where learning experiences are dynamically constructed taking into account Learner's profiles and pedagogical templates.

The framework presented in this thesis goes beyond the domain of eLearning and is able to accommodate approaches that aim at repurposing and use of the underlying digital library content in other domains as well such as eScience, eResearch etc. That means that this framework can be easily applied in other types of applications, since it supports multiple contexts and views of the digital objects of a digital library. To achieve that, the framework exploits METS [METS, 2005], which is the first widely-accepted standard designed specifically for digital library metadata. Using the approach proposed in this framework, the construction of audiovisual learning objects is possible, containing information about their educational use through learning object metadata, while in parallel retaining their audiovisual characteristics described using audiovisual standards (e.g. MPEG7).

A challenging problem that is also addressed by this framework is how these audiovisual learning objects are afterwards combined and organized in meaningful structures to create learning experiences that are delivered through eLearning Applications (e.g. Learning Management Systems – LMSs) to Learners to satisfy their individual needs. The provision of efficient personalization services to Learners beyond “one size fits all” solutions is considered as a necessity to cope with this problem and generally with the overwhelming amount of available learning material existing in Digital Libraries. For that reason an integral part of this framework is the dynamic creation of pedagogically-sound personalized learning experiences from (audiovisual) learning objects taking into account the variety of the Learners and their individual needs. This framework defines a model for the representation of abstract training scenarios (Learning Designs) encoded in an instructional model, where pedagogy is clearly separated from content. Appropriate

Learning Designs are applied from the personalization processes to the construction of learning experiences where reusable learning objects are bound to the training scenario at run-time according to the Learner's individual needs and preferences.

The framework and the architecture presented in this thesis were the basis of two European Projects architectures and their implementation:

- DELOS II Network of Excellence (IST – 507618) subproject “Interoperability of eLearning applications with digital libraries”, and
- LOGOS STREP Project (IST-4-027451) “Knowledge-on-Demand for Ubiquitous Learning”

Moreover, parts of the work presented in this thesis have been published in a number of peer-reviewed conference proceedings and technical reports. Finally, this work represented the basis for three diploma theses in the Laboratory of Distributed Multimedia Systems and Applications of the Electronic and Computer Engineering Department of the Technical University of Crete.

Publications & Technical Reports

Several parts of the work presented in this thesis have been published in the following Conference Proceedings:

1. Arapi P., Moumoutzis N., Mylonakis M., Stylianakis G., Theodorakis G., Christodoulakis S. (2008): “Design, Implementation and Experimental Evaluation of a Pedagogy-Driven Framework to Support Personalized Learning Experiences”, In the Proceedings of the 2nd LOGOS Open Workshop on “Cross-Media and Personalized Learning Applications with Intelligent Content” (LAIC 2008), September 2008, Varna, Bulgaria.
2. Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Framework and an Architecture for Supporting Interoperability between Digital Libraries and eLearning Applications”, Book chapter in “Digital Libraries: Research and Development”, Lecture Notes in Computer Science, Springer Berlin/Heidelberg, Volume 4877/2007, pp. 137-146.
3. Arapi P., Moumoutzis N., Mylonakis M., Theodorakis G., Stylianakis G. (2007): “Supporting Personalized Learning Experiences within the LOGOS Cross-Media Learning Platform”, In the Proceedings of the Workshop on Cross-Media and Personalized Learning Applications on top of Digital Libraries (LADL2007) in conj. with ECDL2007 Conference, September 2007, Budapest, Hungary.
4. Arapi P., Moumoutzis N., Mylonakis M., Theodorakis G., Christodoulakis S. (2007): “A Pedagogy-driven Personalization Framework to Support Automatic Construction of Adaptive Learning Experiences”, In the Proceedings of the 6th International Conference on Web-based Learning (ICWL 2007), August 2007, Edinburgh, United Kingdom.
5. Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Pedagogy-driven Personalization Framework to Support Adaptive Learning Experiences”, In the Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007), July 2007, Niigata, Japan.
6. Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Framework and an Architecture for Supporting Interoperability between Digital Libraries and eLearning Applications”, In the Proceedings of the DELOS Conference on Digital Libraries, February 2007, Tirrenia, Pisa, Italy.
7. Christodoulakis S., Arapi P., Moumoutzis N., Mylonakis M., Patel M., Kapidakis S., Papatheodorou C., Arahova A., Vagiati B., Konsolaki H. (2006): “Interoperability of eLearning Applications with Digital Libraries”, In the

Proceedings of the 10th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2006), September 2006, Alicante, Spain

8. Arapi P., Moumoutzis N., Christodoulakis S. (2006): “ASIDE: An Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications”, In the Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), July 2006, Kerkrade, The Netherlands.
9. Christodoulakis S., Arapi P., Moumoutzis N., Patel M., Kapidakis S., Arahova A., Bountouri L. (2005): “Interoperability of eLearning Applications with Audiovisual Digital Libraries”, In the Proceedings of the 9th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2005), September 2005, Vienna, Austria.

Moreover, several parts of this work have been included in the following technical reports of DELOS and LOGOS projects:

- Christodoulakis S., Arapi P., Mylonakis M., Moumoutzis N., Patel M., Kapidakis S., Vagiati V., and Konsolaki H.(2006): “D5.4.2 - Demonstrator of mapping between the eLearning and AV content description standards”, Deliverable, DELOS Project, Submission date: 25/07/2006.
- Lyon L., Patel M., Christodoulakis S., Arapi P., Moumoutzis N., Kapidakis S., Doerr M., Iorizzo D., and Tudhope D. (2006): “D5.0.2 - Status report for Work Package 5”, Deliverable, DELOS Network of Excellence, Submission date: 12/09/2006.
- Pemberton L., Arapi P., Moumoutzis N., Horváth Z., Markus Z. (2007): “Report on Work Package 2: Modelling of Cross-Media Learning Processes and Platform Architecture for Ubiquitous Learning”, Deliverable D3, LOGOS Project, Submission date: 30/04/2007.
- Moumoutzis N., Arapi P., Stockinger P. (Eds.) (2008): “D6 - Report on work package WP3: LOGOS subsystem for transforming digitised knowledge in courseware objects”, Deliverable D6, LOGOS Project, Submission date: 28/01/2008.
- Arapi P., Moumoutzis M., Horváth Z. (2009): “Report on task T5.4: Enhancement of the LOGOS platform functionality”, Deliverable D11, LOGOS Project, Submission date: 26/02/2009.

Dedication

-- *To my family and my friends,*
the strongest foundations of my life that keep me stable --

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Chapter 1. INTRODUCTION

1.1. General

Nowadays, the rapid development of technology highlighted the need for continuous training and acquiring new skills. In this society Information and Communication Technology is both a catalyst and a necessity [van Weert T., 2005]. Consequently, there has been a rapidly growing interest in the provision of lifelong learning opportunities both in workplace and home environments. To keep up with developments workers need to adapt continuously and acquire new competences. The increasing rate of new discoveries and new information enhanced the need for innovative ways of making meaning to cope with such overwhelming amount of information.

In this context, the traditional forms of instruction are many times not adequate due to the natural limitations (time and space) they imply and their high cost. Without overriding them, the traditional forms of instruction have been enriched with new approaches that have a strong technological underlying base. eLearning infrastructures have been developed that are based on specialized information systems that allow for the development, management and provision of advanced instructional services anytime, anywhere. For the development of such systems (eLearning systems/applications) not only the technological advancements in information and communication technologies are being exploited but also the areas of cognitive science and the instructional-pedagogical theories.

On the other hand, libraries have been always being an important source of learning resources. The technology evolution transformed the classic libraries into digital libraries that arose from the need to efficiently host and serve the huge amount of information that now exists in the form of digitized content. In a digital library, knowledge providing content comes in a variety of sizes and formats. Such content can vary from being as small as an image to being as large as an application, from being as simple as a sequence of hypertext markup language pages to being as complex as a course module with audio-video components. When such materials are made available over the Internet, a suitable technology should be provided which would enable users to perceive the value of the content. This aids users in filtering irrelevant digital resources without difficulty. Such information referred to as metadata provides additional information about a digital resource and can figuratively be considered to be the face of the content.

Digital libraries' and eLearning Applications' roles are complementary and if used together they could efficiently support learning purposes. eLearning Applications would be immensely more valuable if they could effectively use the wealth of information that exists in Digital Libraries. Ideally, the Learners should be able to find and organize

effectively the learning resources they want, adapting the learning process to their individual needs, their available time, their preferences and the learning style that fits them better. The individual learning needs and characteristics of the Learners, such as their learning style, their educational level, their previous knowledge and their learning goals are considered as important parameters for the construction of personalized learning experiences beyond “one size fits all” logic. The term “personalized learning” is used by the eLearning community to describe services provided by an eLearning system for the adaptation of the learning content and the learning process in order to be able to deliver different learning experiences to each Learner with ultimate goal a more effective and productive learning.

However, the current situation is quite different from this theoretically logical harmonic cooperation and has to do with the lack of effective support of digital library applications like learning. Applications are well known to be long living, and typically they have longer life than systems. Thus they tend to create their own standards and support infrastructures based on those standards. These independent infrastructures and applications however do not exploit the vast wealth of information in digital libraries, and they do not interoperate effectively and efficiently with them. It is crucial to bridge this interoperability gap between digital libraries and eLearning applications in order to enable the construction of eLearning applications that easily exploit digital library contents.

In order to develop solutions for the interoperation of digital libraries with eLearning applications to be able for eLearning applications to exploit the wealth of content residing in digital libraries, we should first approach them from a conceptual point where both sides and their corresponding objects are well defined and afterwards based on their standards and protocols to develop appropriate mechanisms for their cooperation.

In the rest of this chapter we introduce the concept of interoperability in general, the term “digital object” and the overloaded with definitions term of “learning object” and how it is differentiated from a digital object. Thereafter, we approach the multilevel problem of interoperability between digital libraries and eLearning applications from a standards, objects and infrastructures point of view to continue with the definition of the envisioned scenario and scope of this thesis as well as its goals and objectives.

1.2. Interoperability

The ISO/IEC 2382 Information Technology Vocabulary defines interoperability as “the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units”.

Interoperability in general is concerned with the capability of differing information systems to communicate. This communication may take various forms such as the transfer, exchange, transformation, mediation, migration or integration of information. [Patel et al., 2005]

Ouksel and Sheth identify four types of heterogeneity which correspond to four types of potential interoperability [Ouksel and Sheth, 2004]:

- System: incompatibilities between hardware and operating systems
- Syntactic: differences in encodings and representation
- Structural: variances in data-models, data structures and schemas
- Semantic: inconsistencies in terminology and meanings

According to Gradmann [2008], interoperability is an essential feature for federated information architectures to work in heterogeneous settings and over time. However, use and understanding of the concept still are very heterogeneous: interoperability is conceived in an object-related or in a functional perspective, from a user's or an institutional perspective, in terms of multilingualism or of technical means and protocols. Moreover, interoperability is conceived on different abstraction levels: from the bitstream layer up to semantic interoperability. Similarly, Payette S. et al. [1999] argue that interoperability is a broad problem domain that is typically investigated within a specific scope, such as within a particular community (e.g., libraries, commercial entities, scientific communities), within a particular classification of information (e.g., electronic records, technical reports, software), or within a particular information technology area (e.g., relational databases, digital imaging, data visualization).

1.3. Digital Libraries

The Digital Libraries domain is very complex and highly multidisciplinary [Candela et al., 2008]. Naturally, this has created several conceptions of what a Digital Library is, each one influenced by the perspective of the primary discipline of the conceiver(s) [Candela et al., 2008]. Hence, the notion of “Digital Library” is subject to a broad range of definitions and the term “Digital Library” is used to refer to systems that are heterogeneous in scope and yield very different functionality. Fox et al. [1995] observe that the expression ‘Digital Library’ evokes a different impression in each person, ranging from the simple computerisation of traditional libraries to a space in which people communicate, share and produce new knowledge and knowledge products. Specifically, these systems range from digital object and metadata repositories, reference-linking systems, archives, and content administration systems (mainly developed by industry) to complex systems that integrate advanced digital library services (mainly developed in

research environments) [Candela et al., 2008]. On the one end of this range, Digital Libraries are considered to be related to physical libraries performing similar functions, thus creating a hybrid library combining traditional and electronic resources. On the other end, Digital Libraries are considered to be knowledge repositories and services organized as complex information systems. [Unesco, 2003]

The broadest definition that seems to be closest to the approach taken by the research community is:

“Digital Libraries are organized collections of digital information. They combine the structure and gathering of information, which libraries and archives have always done, with the digital representation that computers have made possible” [Lesk, 1997].

A definition that could be considered as a bridge between the research and practicing communities is:

“Digital Libraries are a set of electronic resources and associated technical capabilities for creating, searching, and using information; they are an extension and enhancement of information storage and retrieval systems that manipulate digital data in any medium. The content of digital libraries includes data and metadata. Digital Libraries are constructed, collected, and organized by (and for) a community of users and their functional capabilities support the information needs and uses of that community” [Borgman, 1999].

Another working definition is closer to the practicing community, since it emphasizes on an organizational or institutional setting for the collection of digital works and aspects related to its functioning in the larger context of service:

“Digital Libraries are organizations that provide the resources, including the specialized staff, to select, structure, offer intellectual access to, interpret, distribute, preserve the integrity of, and ensure the persistence over time of collections of digital works so that they are readily and economically available for use by a defined community or set of communities” [DLFS, 1999].

The United Nations Task Force on Digital Libraries gives the following definition:

“Digital Libraries are organized collections of information resources in digital or electronic format along with the services designed to help users identify and use those collections. Digital Libraries promise to provide more effective information services than has been possible in the past, by offering the following advantages: faster delivery, a wider audience, greater availability, more timely information, more comprehensive”.

Neuhold and Niederée try to summarize the various definitions for Digital Libraries as follows: *“A Digital Library is an information system targeted towards a specific community, where content from different sources is collected and managed, content is structured and enriched with metadata,*

and a set of services is offered that makes the content available to a user community via a communication network, typically the Internet”.

This diversity of interpretations leads to a wide range of possible visions for Digital Libraries frameworks and methodologies of use, from the conventional library metaphor to knowledge-based systems.

1.3.1. Multimedia Digital Libraries

Multimedia Digital Libraries are digital libraries, where the managed content is not restricted to the usually mainly textual documents. Such libraries contain, next to the “textual” contents, media types like music, videos, images, maps, and mixtures of different content types (multimedia objects) as they are, for example used in e-Learning or in the documentation of history. Multimedia libraries may also contain content types that were not supported in traditional libraries at all like 3D objects, executable software (e.g. computer games) or callable services. One of the main challenges for a multimedia library is to provide effective access to these types of context (based on adequate indexing) and to provide support for the “real-time” integration of different content types. Some challenges of multimedia libraries are closely related to those of museums and archives that make multimedia representations of their artifacts available online. [Neuhold and Niederée]

1.4. eLearning Applications

Generally, the infrastructure of an eLearning system can be divided into a Learning Content Management System (LCMS) and a Learning Management System (LMS).

1.4.1. Learning Content Management Systems (LCMS)

A Learning Content Management System (LCMS) focuses on content creation, reuse and management and can compress the lifecycle of capturing, delivering, managing and measuring knowledge and learning content reuse in many different ways [Lennox, 2001]. An LCMS is a multi-user environment where learning developers can create, store, reuse, manage, and deliver digital learning content from a central object repository. **LCMS allow users to create, import, manage, search for and reuse small units or 'chunks' of digital learning content/assets, commonly referred to as “learning objects”.** These assets may include media files developed in other authoring tools, assessment items, simulations, text, graphics or any other object that makes up the content within the course being created. **The use of standardized learning metadata structures plus standardized learning object import and export formats** also allows learning objects to be created and shared by multiple tools and learning repositories/digital libraries. To support this interoperability across systems, LCMS should be designed to conform to standard specifications for content metadata, content packaging and content communication.

1.4.2. Learning Management Systems (LMS)

A Learning Management System (LMS), on the other hand focuses on delivering, tracking and managing training/education. The LMS cannot create and manipulate courses; it cannot reuse the content of one course to build another. LMSs range from systems for managing training/educational records to software for distributing courses over the Internet and offering features for online collaboration. In many instances, corporate training departments purchase LMSs to automate record-keeping as well as the registration of employees for classroom and online courses. Student self-service (e.g., self-registration on instructor-led training), training workflow (e.g., user notification, manager approval, wait-list management), the provision of on-line learning (e.g., Computer-Based Training, read & understand), on-line assessment, management of continuous professional education (CPE), collaborative learning (e.g., application sharing, discussion threads), and training resource management (e.g., instructors, facilities, equipment), are dimensions to Learning Management Systems.

Despite this distinction, the term LMS is often used to refer to both an LMS and an LCMS, although the LCMS is a further development of the LMS. LCMSs and LMSs complement each other well. When tightly integrated, information from the two systems can be exchanged, ultimately resulting in a richer learning experience for the user and a more comprehensive tool for the learning administrator.

1.5. Digital Objects

In the broad sense, a digital object (that could be stored in a digital library) is an information object that has a digital form (at least one) and is described with metadata. These, according to the Library of Congress, are:

- **Descriptive metadata:** information relating to the intellectual contents of the object, akin to much of the content of a standard catalogue record: this enables the user of a digital library to find the object and assess its relevance.
- **Administrative metadata:** information necessary for the manager of the electronic collection to administer the object, including information on intellectual property rights and technical information on the object and the files that comprise it.
- **Structural metadata:** information on how the individual components that make up the object relate to each other, including the order in which they should be presented to the user: for example, how the still image files that comprise a digitized version of a print volume should be ordered.

Any object, physical or digital, could be described and discussed in possibly infinite ways, depending on the context. This depends on the perspective from which one approaches

the digital object (e.g. cultural, historical, artistic etc.). McCarthy [2000] gives the following definition: “Contextual information is that extra, associated, related, assumed and perhaps a priori information or knowledge that is required to meaningfully interpret the content of any given information source”. Descriptive metadata are the mechanism for adding contextual information to objects.

The choice of metadata terms used to describe content of a digital object in any collection is (and has to be) based on implicit or explicit assumptions or beliefs about how, when and where the asset is likely to be used and by whom. That is, it is based on assumptions about the context(s) of use of the asset. [Shajabee, 2002]. Moreover, the “how” a digital object has been described through metadata (context) determines the application by which it can be discovered and utilized. Or inversely, the intended use/application affects how a digital object should be described.

Different metadata models have emerged in order to be able to describe different aspects of digital objects depending on the intended use of those objects. For example LOM standard [IEEE LOM, 2002] is widely used to describe digital objects from an educational point of view and CIDOC CRM [CIDOC CRM, 2006] is widely used to describe digital objects from a cultural point of view.

1.6. Learning Objects

Current developments in eLearning have promoted the concept of reusable learning objects. Traditionally, learning was organized in lessons and courses covering predefined objectives. In eLearning environments the material is broken into smaller independent pieces named learning objects that can be used as they are or in combination with other material to form higher level objects covering the learning needs of the users on demand and at the right time. In this context, the fundamental idea behind learning objects is that instructional designers can build small instructional components that can be reused a number of times in different learning contexts [Wiley, 2002]. Learning objects are stand-alone pieces of information that are reusable in multiple contexts, depending on the needs of the individual user. In various publications, it is argued that reuse not only saves time and money, but also enhances the quality of digital learning experiences, resulting in efficient, economic and effective learning.

The idea of small, self-contained, reusable components that can be aggregated with other components has been adopted from object oriented programming [Sosteric and Hesemeier, 2004]. Boyle [Boyle, 2003] elucidates the approach by identifying software engineering design principles that have direct relevance to the development of learning objects:

- The first principle is cohesion: each unit should do one thing and only one thing [Sommerville, 2000]. A direct link can be made to the idea of learning objectives

in pedagogical theory. The mapping suggests that each learning object should be based on one learning objective or clear learning goal.

- The second principle is minimized coupling. This principle states that the unit (software module/learning object) should have minimal bindings to other units. Thus, the content of one learning object should not refer to that of another learning object in such a way as to create necessary dependencies.

Both principles are crucial in design for reuse [Boyle, 2003]. The principle of cohesion helps to decide how to partition learning content into reusable components. This process is often referred to as “granularization”, and refers to both the size of the learning object and the decomposition process.

There is a common consensus that a learning object should be [Rehak and Mason, 2003]:

- **Reusable** - can be modified and versioned for different courses;
- **Accessible** - can be indexed and retrieved using metadata;
- **Interoperable / portable** - can operate across different hard/software;
- **Durable** - remains intact across upgrades of hard/software.

Similar characteristics are defined by Downes [Downes, 2004], who argues that learning objects should be:

- sharable: may be produced centrally, but can be used in many different courses;
- digital: can be distributed using the Internet;
- modular: capable of being combined with other resources;
- interoperable: capable of being used by different institutions using different tools and systems; and
- discoverable: users can easily locate the object.

However, confusion continues to exist in practice about what a learning object is, and how it might differ from content files such as a photo, a video clip, or a research report. At what point do typical digital assets like these become learning objects? What distinguishes a learning object from any other sort of learning material? The structure and composite nature of a learning object is still open to interpretation [Metros, 2005; Knight, Gašević, and Richards, 2005].

A main definition that is also supported in this thesis, is that a learning object is a collection of digital materials — pictures, documents, simulations — coupled with a clear and measurable learning objective. This view distinguishes a learning object from an “information object” (akin to a simple fact) — which might have an illustration or other materials attached to it — or from “a content object” such as a video or audio clip, picture, animation, or text document. The key distinguishing feature between these kinds of objects and a learning object is the clear connection to an educational purpose to achieve a specific learning outcome or outcomes. Combining learning objects in different ways, higher-level learning goals can be met, and ultimately, entire courses could even be constructed.

This view has been widely disseminated and is illustrated well by the Learnativity Content Model [Wagner, 2002] (Figure 1.1). The model illustrates the concept of assembling content into higher-level objects; learning objects are assembled into higher-order collections such as courses and curricula. This model is very useful for describing granularity and granularity is very useful to achieving reusability.

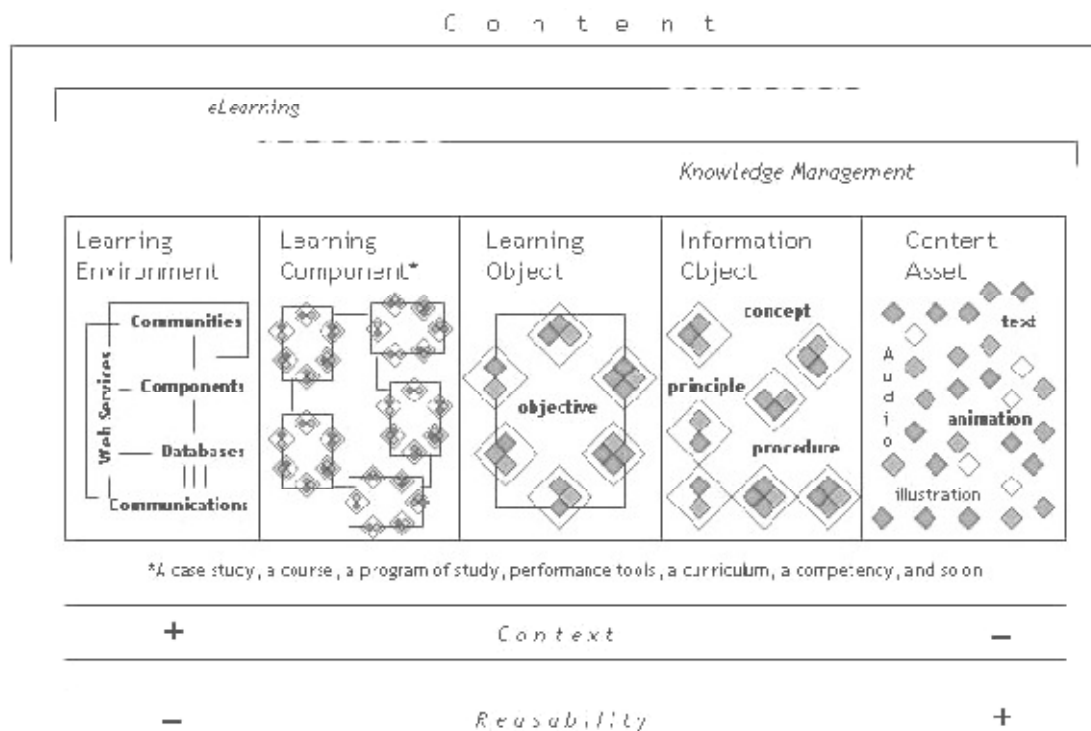


Figure 1.1 The Learnativity content model [Wagner, 2002]

The basic components of the Learnativity content model [Wagner, 2002] are the following:

- **Content Asset:** Content Assets include raw media such as images, text snippets, audio clips, applets, etc.

- **Information Object:** A text passage, Web page(s), applet, etc. that focus on a single piece of information. It might explain a concept, illustrate a principle, or describe a process. [Single] exercises are often considered to be information objects.
- **Learning Object:** In the Learnativity content model a Learning Object is a collection of Information Objects that are assembled to teach a single learning objective.
- **Learning Component:** A Learning Component is a generic term for things like lessons and courses are typically connected with a higher level learning objective and have multiple learning objectives since they are composed of multiple Learning Objects.
- **Learning Environment:** The “Learning Environment” is a catch-all phrase for the combination of content and technology with which a learner interacts. A combination of learning components with communication tools and/or other features that facilitate an e-learning experience can be aggregated into a learning environment (e.g. LMS).

It is commonly accepted that there is an inverse relationship between the size of a learning object and its reusability. Fine-grained learning objects or learning object components have the potential to be flexibly assembled into new learning objects, whereas entire courses are often not suitable for use in a different context. This fact is also illustrated in Figure 1.1.

1.7. Learning Experiences and Instructional Design

A learning experience could be compared with a business process where a higher level goal is accomplished by the actor (here the Learner) after experiencing a number of activities with specific objectives, associated with learning objects or services. Different Learners have different characteristics and preferences (e.g. learning style, educational level, previous knowledge etc.) and these affect how these learning experiences should be structured in terms of their activities as well as the content that should support those activities to achieve specific goals. That means that different Learners learn best in different ways and need different workflows of “how and what” is taught, while in parallel may need to master different objectives in order to achieve the same learning goals.

The way that a learning experience should be organized in terms of its structure and content to support a Learner with specific learning characteristics is named “Instructional Design”. Instructional Design is part of Instructional Science, which encompasses theories, models, methodologies and tools for instruction [Mizoguchi & Bourdeau, 2000].

Instructional Design is an engineering activity for which the artifact is some instructional product to help a learner acquire some knowledge or skill [Merrill, 2001]. This activity applies strategies and techniques derived from behavioral, cognitive, and constructivist theories to the solution of instructional problems [Mizoguchi & Bourdeau, 2000]. Instructional Design is a methodology for systematic planning and developing curriculums, courses and educational media. It helps teachers, educators and training professionals to design effective, efficient and appealing instruction that meets requirements of specific learning goals, learners' characteristics and organizational needs.

Instructional Design theories are prescriptions for designing instructional products to optimize the learning outcome [Merrill, 2001]. They describe methods of instruction together with situations in which those methods should be used [Reigeluth, 1999]. According to [Dick, Carey, and Carey, 2000], the underlying questions about instructional design are from a pragmatic viewpoint 1) what to teach, and 2) how to teach.

In order for the learner to acquire higher order cognition skills (analysis, synthesis, and evaluation), the need for instructional design, which facilitates, promotes and supports activity based learning, must be realized. Learning Activities typically consist of some form of task(s), associated tools which could be used to perform the task(s), and appropriate learning content.

However, although there is a variety of “instructional design” guidelines and approaches in theory, these have not appropriately linked with practice, making the development of algorithms and systems for personalization in eLearning difficult.

1.8. The multilevel problem of interoperability between digital libraries and (eLearning) Applications

The problem of interoperability between digital libraries and (eLearning) applications is a complex and multi-level one. This problem is analyzed in the following sections from a standards, objects and infrastructures point of view.

1.8.1. A standards point of view

The problem of interoperability between digital libraries and eLearning applications can be seen as a stack of conceptual layers where each one is built on top of the previous one (left part of Figure 1.2): There are different data representations, objects, concepts, domains, contexts and metacontexts in the layer stack that should be efficiently managed in a standard way. Metadata models are languages that are used to represent the knowledge in a particular application area. Each metadata model is shown as a vertical bar on this stack to cover a specific region that represents the parts that the model tries to capture and describe in a standard way. If one places different metadata models besides this stack, he may identify gaps and intersection regions so that being apparent where the interoperability problems among these models occur. Interoperability

problems exist also in the overlapping areas. But in those areas solving the problem of interoperability is easier and can be solved with standard methods (e.g. by means of mappings). The major problems arise in the areas with no overlaps between the two metadata standards. The right part of Figure 1.2 shows such a picture in the case of MPEG7 [MPEG7, 2001, 2003] and SCORM [SCORM, 2004], the major metadata standards in the audiovisual and eLearning domains respectively. It is apparent from this graphical presentation that MPEG7 and SCORM are not completely overlapping meaning that we need additional models to provide interoperability mechanisms between them (see Appendix 1: Semantic mapping between MPEG7 and LOM).

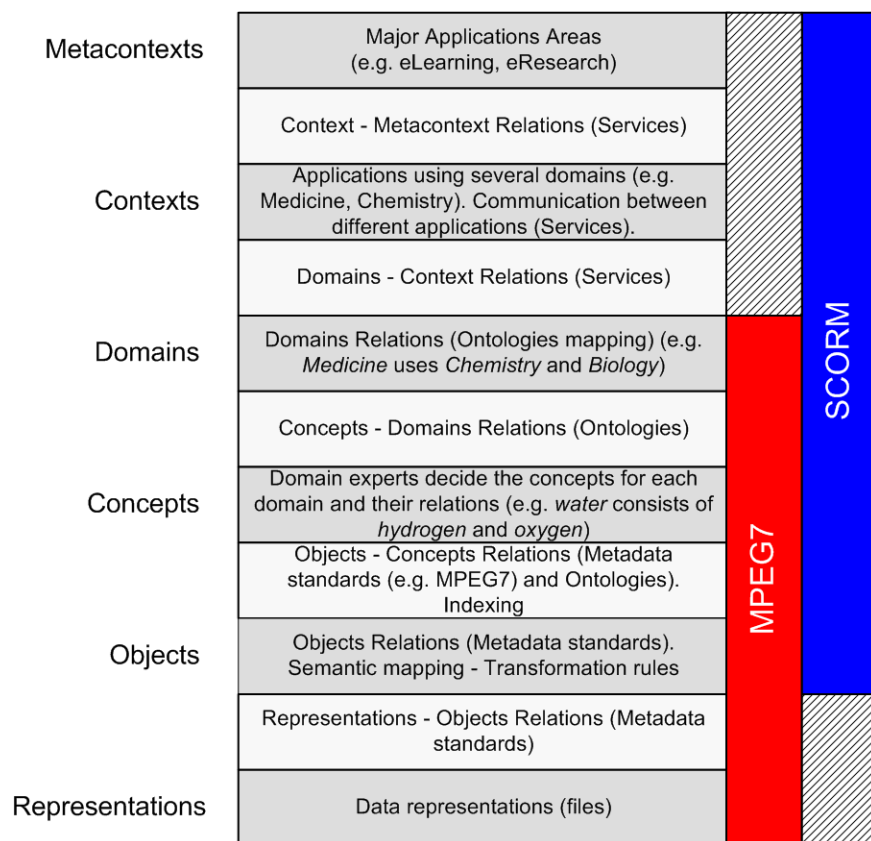


Figure 1.2 The multilevel problem of interoperability between digital libraries and (eLearning) Applications

For example, SCORM contains an educational part that cannot be mapped directly or indirectly, completely or partially to MPEG7 elements. That is because MPEG7 does not include information about possible educational use of audiovisual (A/V) objects because it is not an application-specific context metadata standard. However, educational information is very important in the case that MPEG7 (and generally an A/V digital library) is used for educational purposes. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions, which will form the basis for applications that provide the needed effective and efficient access to audiovisual content, which can not be represented in SCORM.

Modifying the above standards (e.g. mixing parts of them) would not be a good and right idea, since they have been developed to satisfy the needs of different communities, although several works (mentioned in Chapter 1) tried to mix them recognizing the importance of the standards' non overlapping areas and in parallel the inappropriateness of semantic mapping solutions on those areas. It would be not right and generic to add elements from an eLearning standard to MPEG7, since it is not eLearning-oriented, or adding MPEG7 elements to SCORM, since learning resources in SCORM are not always audiovisual.

The above shortcomings are crucial in order to develop an integrated model that will allow for the unified description of audiovisual learning materials i.e. unified metadata descriptions of audiovisual objects and their parts from one or more educational perspectives.

1.8.2. An objects point of view

According to Downes [2003], whether something counts as a LO, depends on whether it can be used to teach or learn, and this can only be determined by its use, not by its nature. The Warwick University group [2004] support Downes' view that *use determines whether or not an object becomes a learning object*. However, they make a semantic distinction between “asset data”, which consists of images, animation, VR models, etc. and “content object”, which would also include the metadata that provides a context. Sosteric and Hesemeier [2002] emphasize the intent of the object more than the structure. According to them, *a LO is “a digital file (image, movie, etc.) intended to be used for pedagogical purposes, which includes, either internally or via association, suggestions on the appropriate context within which to utilize the object”*. They claim that a newspaper article would not be considered to be a LO simply because it could be used for learning. *It must be linked to “pedagogical purposes”*. Polsani [2004], defines a LO as “a form of organized knowledge content involving learning purpose and reusable value.” According to these authors, *an information object becomes a LO when it is designed to be used by itself or in combination with other media objects to facilitate or promote learning*. To be a LO it must be packaged and made available for distribution as a lesson of some kind. Duval & Hodgins [2004] refer to LOs as containing information objects, which in turn might contain raw media elements. They refer to aggregate assemblies that contain LOs and other aggregate assemblies. Koper [2003] refers to LOs as “units of learning” defined as *digital objects with a specific educational purpose*. However, he specifically excludes full courses from his definition. Ally [2004] defines a LO as *“any digital resource that can be used and re-used to achieve a specific learning outcome or outcomes”*. The three key words in these definitions are *digital, reusable, and learning outcome*. [McGreal, 2004]

Thus, a digital object is not a learning object, unless:

- 1) It has a clear pedagogical purpose (learning outcome/objective) that is appropriately linked to the object through learning metadata

- 2) It has the right granularity and content for the target pedagogical purpose

From all the above statements it is clear that use (learning context) determines whether or not a digital object becomes a learning object. Depending on the learning context, a digital object may be appropriate or not in terms of its granularity and content to become a learning object. In general, the broader the target learning objective is the bigger is expected to be the granularity of a learning object. A learning objective is a single measurable or verifiable step on the way to a learning goal. Learning objectives say what a learner is expected to do or learn and how an acceptable level of achievement will be verified. So, depending on the case, the following scenarios are relevant:

- A digital object may be used as is in terms of its granularity and content to serve a pedagogical purpose. The digital object should be appropriately described with learning metadata to be linked with this pedagogical purpose in order to become a learning object.
- A part (or parts) of a digital object may be appropriate to serve a pedagogical purpose. To become a learning object the new object should be linked to the target pedagogical purpose through learning metadata.
- A digital object (or part of it) may be combined with other digital objects (or parts of them) in order to form a higher level unit (composite object) to serve a pedagogical purpose. The new object should be finally described with learning metadata to become a learning object.

A digital object can have many educational uses depending each time on the learning context. However:

- 1) Is it possible to predict all possible uses of a digital object?
- 2) If we don't know the target educational use of a digital object how can we know if the granularity and content of a digital object is appropriate?
- 3) Given 1) and 2), how, when and by whom can a digital object be adapted and described with learning metadata in order to be able to be exploited by eLearning Applications?

From the above discussion it is apparent that transforming digital objects to learning objects in order to be able to be exploited by eLearning Applications is not a straightforward and a one-to-one mapping process. Use determines whether a digital object becomes a learning object, but we cannot predict all possible educational uses of a digital object or whether we should use a part of it, or to combine it with other objects to serve all of them. Finally, learning metadata are important in order for a digital object to

be exploited by eLearning applications, but describing a digital object without a clear educational context is not possible.

1.8.3. An infrastructures point of view

Figure 1.3 presents how different roles (e.g. Courseware Authors, Instructors, Learners) are currently using eLearning Applications and to what extent and how digital libraries contents are exploited from the later ones.

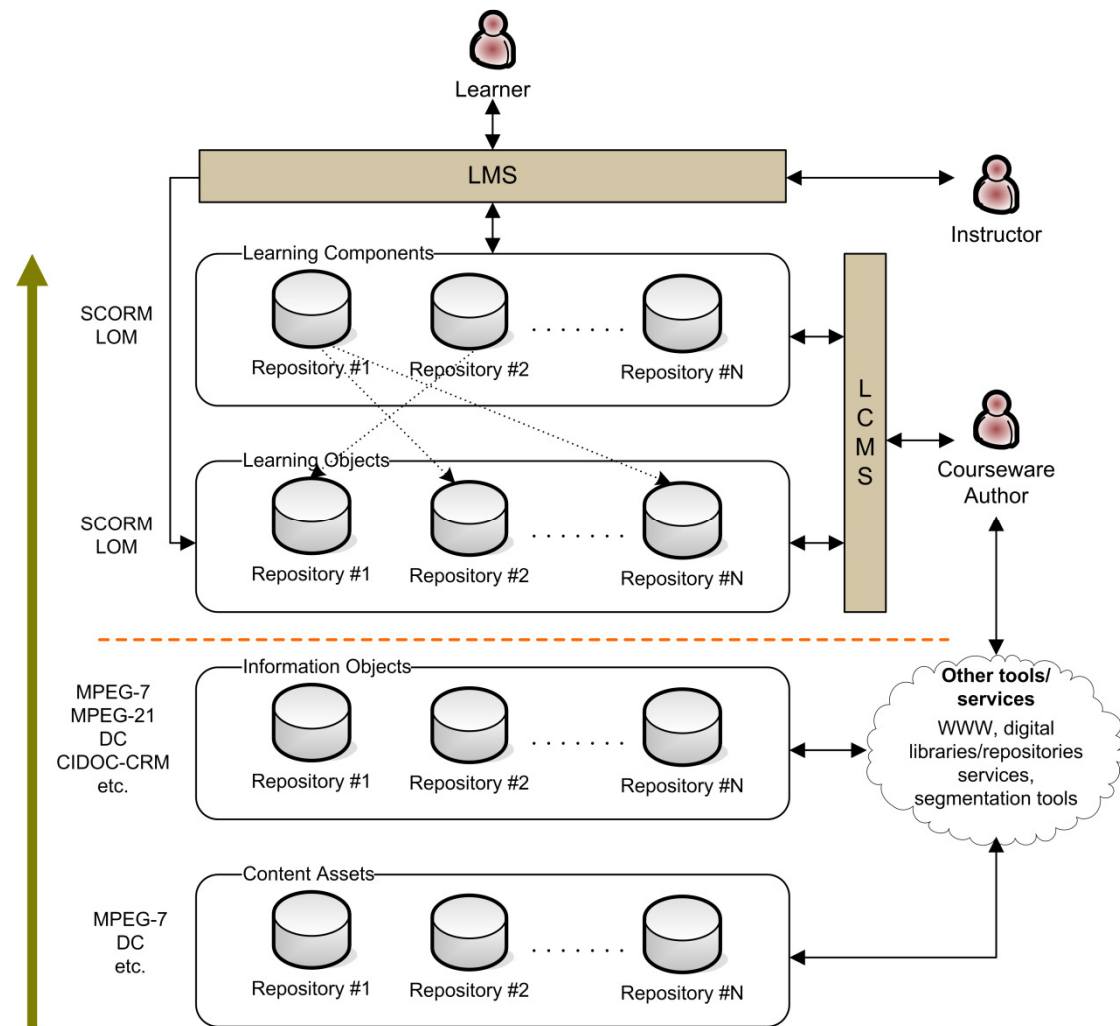


Figure 1.3 Current exploitation of digital libraries contents from eLearning Applications

The authoring procedure that is currently followed in eLearning environments for the creation of courseware is similar to the procedure followed in traditional learning environments. The first step for the author is to define a number of learning objectives that should be fulfilled in order for the terminal objective (learning goal) to be satisfied. Thereafter, the author is trying to find appropriate learning content to create learning units (LOs) to support these objectives.

An Author for the creation of LOs through an LCMS either discovers and reuses existing LOs that (s)he repurposes depending on the target educational context or (s)he starts to

create a new one. In both cases (s)he may need to find appropriate digital objects (Content Assets and/or Information Objects in terms of Learnativity Content Model). However, in order for these digital objects to be accessible from the LCMS, they should be represented and described according to eLearning standards (e.g. SCORM, LOM) and stored in a learning objects/assets repository. Although LOs must be described with educational metadata from their nature, this is not always relevant with digital objects. Digital Objects may come from a number of different sources and described in various ways, since they can be used in a number of different applications. For that reason, **finding the appropriate Digital Objects that will be used in the construction of LOs is not traditionally done through an LCMS, but using a number of different tools and services. It is hard to discover them, since they reside in various places (digital libraries/repositories), they are described in various ways and no common interfaces and protocols exist to gain access to this content.**

But even when the right digital objects to be included in a LO are found, they lose their useful descriptions when these are retrieved and incorporated in the LO. That happens because the author of the LO actually retrieves and uses the physical content of the digital object leaving back its metadata. **However, these characteristics (e.g. technical) may be important for the use and delivery of this object, even if it has been incorporated in the context of a larger object (e.g. cross-media delivery).**

After the constituent digital objects of the LO have been adapted, the LO should be appropriately represented and described using eLearning standards (e.g. SCORM, LOM) in order to be able to be discovered, used and reused by eLearning applications.

However, although eLearning standards ensure some level of interoperability and reusability, two main problems act against them:

- 1) There is no commonly accepted definition on what exactly a LO is and what should be the granularity of such an object. Different content models have emerged in order to address this problem resulting in different implementations of LOs. A review of the available content models can be found in [Verbert and Duval, 2004, 2008; Balatsoukas, Moris, and O'Brien, 2008].
- 2) Different pedagogical approaches exist, requiring different implementations of LOs. Many times the pedagogical approach is strictly bound with the LO, reducing the possibilities for reusing this object in different contexts.

The above problems make difficult the exploitation of LOs from personalization systems in order to generate higher level objects in the form of learning experiences to satisfy the needs of different learners.

Similarly with LCMSs, the minimum chunk of information that is able to be used and provided by an LMS is a Learning Object (SCO in terms of SCORM) consisting of digital assets. From this traditional point of view, an LMS will never need (and consequently their users will never be able) to exploit directly the content residing in digital libraries/repositories, unless they are educational digital libraries/repositories containing reusable learning objects that conform to educational standards like SCORM.

This could be partially explained as follows. In most cases, LMSs follow an instructionism approach, i.e. they are teacher-focused, skill-based, product-oriented, non-interactive and highly prescribed. However, different learners have different characteristics.

This approach is well-suited for specific groups of learners, especially those that are characterized by a theoretical-oriented learning style or those that prefer reflective observation of prescribed material. However there are many learners whose learning attitude is oriented towards active experimentation and social interaction. This kind of learning attitude is better captured by constructivist-oriented approaches, where Learners have a more active role. In such an approach, Learners could undertake the role of the author or better the instructor and construct knowledge assets that are meaningful for them from a number of different resources. In this scenario, gaining access to the wealth of content that is available on digital libraries/repositories, organizing it and annotating it with learning metadata from their point of view is of great importance.

1.9. Envisioned scenario and scope of this thesis

The envisioned scenario in this thesis supports the construction of high-quality learning content that is assembled in a number of different ways from audiovisual objects to support the needs of different Learners and is able to be delivered in the form of learning experiences through a number of different channels (e.g. devices).

In order to support this scenario, it is of great importance to provide the ability to re-purpose or enable others to **locate** and **re-purpose** digital objects in different (educational) contexts. “Repurposing” or “reauthoring” is the process of adaptation of a given audiovisual resource in order to produce a new version of it which may be composed of parts coming from different source documents. A repurposed or re-authored version should correspond better to the expectations, needs and interests of a target user group. **The re-authoring process is a multi-step and complicated activity that is not currently supported by appropriate technologies. As a result, both content providers and content users are not able to exploit effectively the available learning resources residing in multimedia digital libraries in various contextualized uses and especially in formal and informal learning scenarios.**

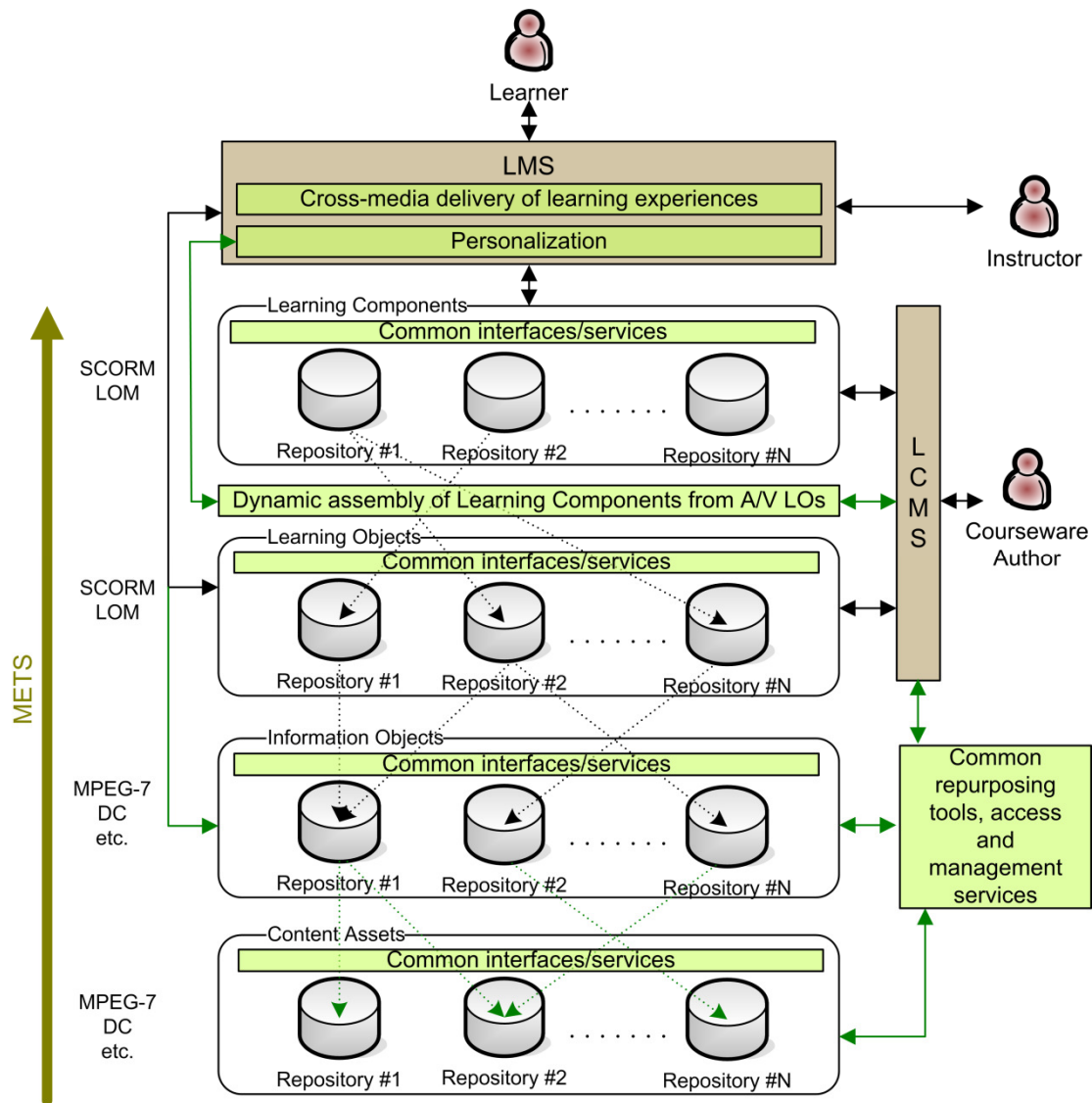


Figure 1.4 Envisioned scenario

In the envisioned scenario illustrated in Figure 1.4 the red borderline of the conceptual architecture presented in Figure 1.3 has been removed. In this scenario eLearning Applications are able to access and repurpose digital content at each level starting from content assets using common interfaces/services. The repurposing process is done at each level using common repurposing tools, access and management services to produce objects of the next level. An important feature of this scenario is personalization through dynamic creation of Learning Components from A/V LOs to satisfy the needs of different learners (learning style, educational level, prior knowledge etc.). This functionality can be used both by Learners and Courseware Authors through an LMS and LCMS respectively for the creation of personalized learning experiences. Courseware Authors can use this functionality to semi-automatically create their courses to match a specific learner profile or stereotype.

To support the above scenario the following requirements must be met.

1.9.1. Supporting multiple (educational) contexts views of digital objects

Repurposing digital objects for different educational contexts requires a flexible data model for the uniform treatment of digital objects. This model should support multiple contextual views (through descriptive metadata) of digital objects, in order to be able for these objects to be discovered, used and reused by various applications. These views of a digital object should not be attached in the initial object, but should reside at an upper level (context level) referencing the original object. In parallel, access to the original object administrative (e.g. audiovisual) characteristics should be possible in order to be able to use this object through different media (e.g. devices). Moreover, the structural model (structural metadata) for the representation of the structure of the digital object should be neutral and independent from the context. Finally, repositories at each level should expose common interfaces and services to applications. This can be done with the use appropriate standards as IMS DRI [IMS DRI, 2003].

1.9.2. Supporting pedagogy-driven personalized learning experiences

Different Learners have different learning styles, educational levels, previous knowledge and goals and all these have been proved as important parameters that should be taken into account in personalization processes. Pedagogy (the “how-to-teach”) should be also taken into account and should be separated and independent from content (the “what-to-teach”), allowing effective creation of pedagogy-driven personalized learning experiences where appropriate content is bound to the training scenario at run-time according to the Learner Profile, and reusability of training scenarios and learning content in several instructional contexts. In existing approaches, even in current eLearning standards and specifications, content is bound to the training scenario at design time prohibiting the construction of real personalized learning experiences, where Learner needs and preferences expressed in Learner Profiles affect both the “how” and “what-to-teach”.

1.10. Goal, objectives, and contribution of this thesis

The goal of this thesis is to provide solutions to support the construction of eLearning applications on top of Digital Libraries in order to be able for eLearning applications to effectively exploit the wealth of content residing in Digital Libraries. Towards this end, this thesis proposes a generic interoperability/repurposing framework and a service-oriented architecture to support the envisioned scenario that has been previously presented. This Architecture Supports Interoperability between Digital Libraries and ELearning applications (ASIDE) in a dynamic eLearning environment where learning experiences are dynamically constructed taking into account user profiles and pedagogical templates.

This framework goes beyond the domain of eLearning and is able to accommodate approaches that aim at repurposing and use the underlying digital library content in other

domains as well such as eScience, eResearch etc. That means that this framework can be easily applied in other types of applications, since it **supports multiple contexts and views of the digital objects of a digital library**. To achieve that, the framework exploits METS [METS, 2005], which is the first widely-accepted standard designed specifically for digital library metadata. METS is intended primarily as a flexible, but tightly structured, container for all metadata necessary to describe, navigate and maintain a digital object. Using the approach proposed in this framework, the construction of audiovisual learning objects is possible, containing information about their educational use through learning object metadata, while in parallel retaining their audiovisual characteristics described using audiovisual standards (e.g. MPEG7).

An integral part of this framework is how these audiovisual learning objects are afterwards combined or organized in meaningful structures to create learning experiences that are delivered through LMSs to Learners to cover their individual needs. The provision of efficient personalization services to Learners beyond “one size fits all” solutions is considered as a necessity to cope with this problem and generally with the overwhelming amount of available learning material existing in Digital Libraries. For that reason a framework is provided that allows for the dynamic creation of pedagogically-sound personalized learning experiences from (audiovisual) learning objects taking into account the variety of the Learners and their individual needs. This framework defines a model for the representation of abstract training scenarios (Learning Designs) encoded in an instructional model, where pedagogy is clearly separated from content. Appropriate Learning Designs are applied from the personalization processes to the construction of learning experiences where reusable learning objects are bound to the training scenario at run-time according to the Learner’s individual needs and preferences.

Some of the research issues that this thesis is dealing with in order to support effective personalization are the following:

- Domain modeling: Appropriate representation of learning resources is necessary in order to specify important metadata and the semantics of the learning objects. This representation should exploit available metadata standards (such as IEEE/LOM) and extending them to accommodate representation of semantics of learning material based on semantic web and knowledge representation technologies. Another relevant issue is the granularity of learning objects as well as the way of synthesizing learning objects from digital objects residing at digital libraries.
- Learner modeling: In order to be able to provide effective personalized learning experiences, important parameters that affect learning should be investigated. Learners’ needs and preferences should be identified and appropriately represented in a Learner Model. Moreover, methods and assessment instruments

for the evaluation of the psychological profile of the Learner (e.g. learning style) as well as the representation and the determination of learning objectives are relevant. The correlation of learner models with learning object metadata specifications to propose appropriate matching mechanisms for the selection of learning objects satisfying user preferences is also relevant.

- **Instructional modeling:** Effective learning services should be based on sound pedagogical approaches. There is a convergence in the research community that pedagogy is important and should be represented in a consistent way [Arapi et al., 2007a, 2007b, 2007c; Capuano et al., 2005; Dagger et al., 2005; Dagger et al., 2004; Meisel et al., 2003]. Several pedagogical models are available as well as instructional theories that can be exploited to create specific training scenarios to teach specific subjects (see also below, 2.5). It is necessary to have a rich instructional model able to support the different pedagogical models and instructional theories. Moreover, this model should accommodate flexible structures in training scenarios composed of learning activities as well as information regarding the individual learning styles, educational level and preferred difficulty of learners. In addition, the pedagogical models should be reusable and separated from content, allowing appropriate learning resources according to the Learner profile to be bound to the training scenario at run-time. Instructional modeling is closely related to adaptation modeling (see below) as it provides a systematic way of creating pedagogically sound personalized learning experiences. The major research issue here is to develop, assess and refine a rich instructional model taking into account related standards such as the IMS Learning Design and overcoming their shortcomings.
- **Adaptation modeling:** Appropriate specification of rules and algorithms is necessary for creating pedagogically sound personalized learning experiences that satisfy the needs and preferences of Learners expressed in Learner profiles. Several research issues arise here: how the learner profiles are used in combination with the instructional model, how individual learning styles are used and how learning styles taxonomies can facilitate the creation of abstract training scenarios to be used in content adaptation and adaptation of presentation.

The framework and the architecture proposed in this thesis were initially developed and implemented in DELOS II Network of Excellence in Digital Libraries (IST – Project Record Number 507618) JPA2 subproject in a service-oriented architecture above an experimental digital library of audiovisual content. Within the LOGOS Project “Knowledge-on-Demand for Ubiquitous Learning” (IST-4-027451), the framework and the architecture was adapted in order to design and implement a Knowledge-on-Demand ubiquitous learning platform, providing effective personalized learning services to

support learning anywhere, anytime exploiting alternative delivery channels and related devices that go beyond the traditional web-based learning approaches.

1.11. Thesis Structure

In the next chapter (Chapter 2) we present the work that is directly or indirectly related to this thesis. In particular, the first part of this chapter focuses on the interoperability standards and specifications that have been used in this thesis coming from the eLearning and digital libraries/repositories domain and the second part has to do with personalization in eLearning as well as the relevant systems in this area and their shortcomings.

In Chapter 3 a generic interoperability framework and an architecture is presented for supporting interoperability between digital libraries and (eLearning) applications. This framework could be also applied to other types of applications built on top of digital libraries, although in this thesis we focus on eLearning applications.

Chapter 4 we give an example of the application of the framework for the dynamic pedagogy-driven creation of personalized learning experiences. The procedure of the environment setup (Author's perspective) is described, in order to support the generation of personalized learning experiences according to this framework, as well as the personalization process as it is initiated and experienced by the Learner (Learner's perspective).

In Chapter 5 we present the implementation of the interoperability framework and the personalization framework in the context of two European Projects: DELOS and LOGOS.

Chapter 6 deals with the experimental evaluation of the proposed framework focusing on its personalization aspects.

Finally, in Chapter 7 we conclude the work presented in this thesis, and we summarize its main contributions. We also present some ideas for future exploitation and extensions of the framework presented.

Chapter 2. RELATED WORK

2.1. Introduction

In this chapter, we present the work that is directly or indirectly related to this thesis. This chapter is composed of three main parts: The first part focuses on the interoperability standards and specifications that have been used in this thesis coming from the eLearning and digital libraries/repositories domain. The second part has to do with personalization in eLearning as well as the relevant systems in this area. The third part presents the most related work to the work done in this thesis.

Specifically, the IEEE Learning Object Metadata (LOM) standard will be presented that is used for the description of the educational characteristics of resources. Thereafter, the Sharable Content Object Reference (SCORM) the most well known eLearning standard will be described. SCORM is a content packaging standard that is used in this thesis as the delivery means of learning content to eLearning applications. The Metadata Encoding and Transmission Standard (METS) is a digital library standard and specifically it is a flexible, but tightly structured, container for packaging together all metadata necessary to describe, navigate and maintain digital objects and the complex links among them. In the framework presented in this thesis METS is used as the means to support multiple-(educational) contexts views of multimedia digital objects, while in parallel retaining their audiovisual administrative characteristics. The IMS Digital Repositories Interoperability specification [IMS DRI, 2003] purpose is to provide recommendations for the interoperation of the most common repository functions. These recommendations are implemented in this thesis upon repositories at each level to enable them to present a common interface. The most widely used standard for the description of audiovisual content residing in multimedia digital libraries is the Multimedia Content Description Interface (MPEG7). MPEG7 that is also presented here offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions.

“Transforming” content residing in digital libraries to learning objects and then to learning experiences is not a one-to-one mapping process but requires a sophisticated repurposing architecture and tools. Different Learners have different learning characteristics, needs and preferences and this should affect how the final learning experiences and underlying content should be organized and presented. The parameters that affect learning according to the bibliography are introduced and are taken into account in the framework presented in this thesis in order to create higher level objects that are finally delivered to the Learners by eLearning applications as learning experiences. Adaptive eLearning Systems are systems that are able to generate personalized learning experiences based on Learner’s characteristics. However, although

there are several implementations in this category, (the most relevant ones are referred in this chapter), they are several shortcomings that characterize them.

Finally, we will explain how the approach presented in this thesis overcomes the shortcomings of the most related work in this area.

2.2. Interoperability standards and specifications

In this section some of the most important standards and specifications in eLearning and digital libraries domain will be presented and their role in this thesis will be explained.

2.2.1. Learning Object Metadata (LOM)

The IEEE 1484.12.1 – 2002 Standard for Learning Object Metadata [IEEE LOM, 2002] is an internationally recognized open standard (published by the Institute of Electrical and Electronics Engineers Standards Association) for the description of “learning objects”. The IEEE working group that developed the standard defined learning objects as being “any entity, digital or nondigital, that may be used for learning, education or training”, a definition which has struck many commentators as being rather broad in its scope. IEEE 1484.12.1 is the first part of a multipart standard, and describes the LOM data model. The LOM data model specifies which aspects of a learning object should be described and what vocabularies may be used for these descriptions; it also defines how this data model can be amended by additions or constraints. Other parts of the standard are being drafted to define bindings of the LOM data model, i.e. define how LOM records should be represented in XML and RDF (IEEE 1484.12.3 and IEEE 1484.12.4 respectively).

IMS Global Learning Consortium is an international consortium that contributed to the drafting of the IEEE Learning Object Metadata and endorsed early drafts of the data model as part of the IMS Learning Resource Meta-data specification (IMS LRM, versions 1.0 – 1.2.2).

Feedback and suggestions from the implementers of IMS LRM fed into the further development of the LOM, resulting in some drift between version 1.2 of the IMS LRM specification and what was finally published at the LOM standard. Version 1.3 of the IMS LRM specification realigns the IMS LRM data model with the IEEE LOM data model and specifies that the IEEE XML binding should be used. Thus we can now use the term “LOM” in referring to both the IEEE standard and version 1.3 of the IMS specification. The IMS LRM specification also provides an extensive Best Practice and Implementation Guide, and an XSL transform that can be used to migrate metadata instances from the older versions of the IMS LRM XML binding to the IEEE LOM XML binding.

LOM content model consists of four aggregation levels or levels of functional granularity [IEEE LOM, 2002]. These include:

- **Level 1:** The smallest aggregation level, such as raw media or fragments
- **Level 2:** A collection of Level 1 learning objects, such as a lesson.
- **Level 3:** A collection of Level 2 learning objects, such as a course.
- **Level 4:** The largest level of granularity, such as a collection of courses.

Some of the main things that are achieved with the use of LOM are:

- Creation of well structured descriptions of learning resources. These descriptions should help facilitate the discovery, location, evaluation and acquisition of learning resources by students, teachers or automated software processes.
- Sharing of descriptions of learning resources between resource discovery systems. This should lead to a reduction in the cost of providing services based on high quality resource descriptions.
- Tailoring of the resource descriptions to suit the specialized needs of a community. This may include choosing suitable controlled vocabularies for classification, reducing the number of elements that are described or adding new ones from other resource description schemas.
- Creators and publishers may use the LOM along with other specifications to “tag” learning resources with a description that can be associated with the resource. This will provide information in a standard format similar to that found on the cover and fly-page of a text book.

Data elements describe a learning object and are grouped into categories. The LOMv1.0 Base Schema consists of nine such categories (Figure 2.1):

1. The **General** category groups the general information that describes the learning object as a whole.
2. The **Lifecycle** category groups the features related to the history and current state of this learning object and those who have affected this learning object during its evolution.
3. The **Meta-Metadata** category groups information about the metadata instance itself (rather than the learning object that the metadata instance describes).

4. The **Technical** category groups the technical requirements and technical characteristics of the learning object.
5. The **Educational** category groups the educational and pedagogic characteristics of the learning object.
6. The **Rights** category groups the intellectual property rights and conditions of use for the learning object.
7. The **Relation** category groups features that define the relationship between the learning object and other related learning objects.
8. The **Annotation** category provides comments on the educational use of the learning object and provides information on when and by whom the comments were created.
9. The **Classification** category describes this learning object in relation to a particular classification system.

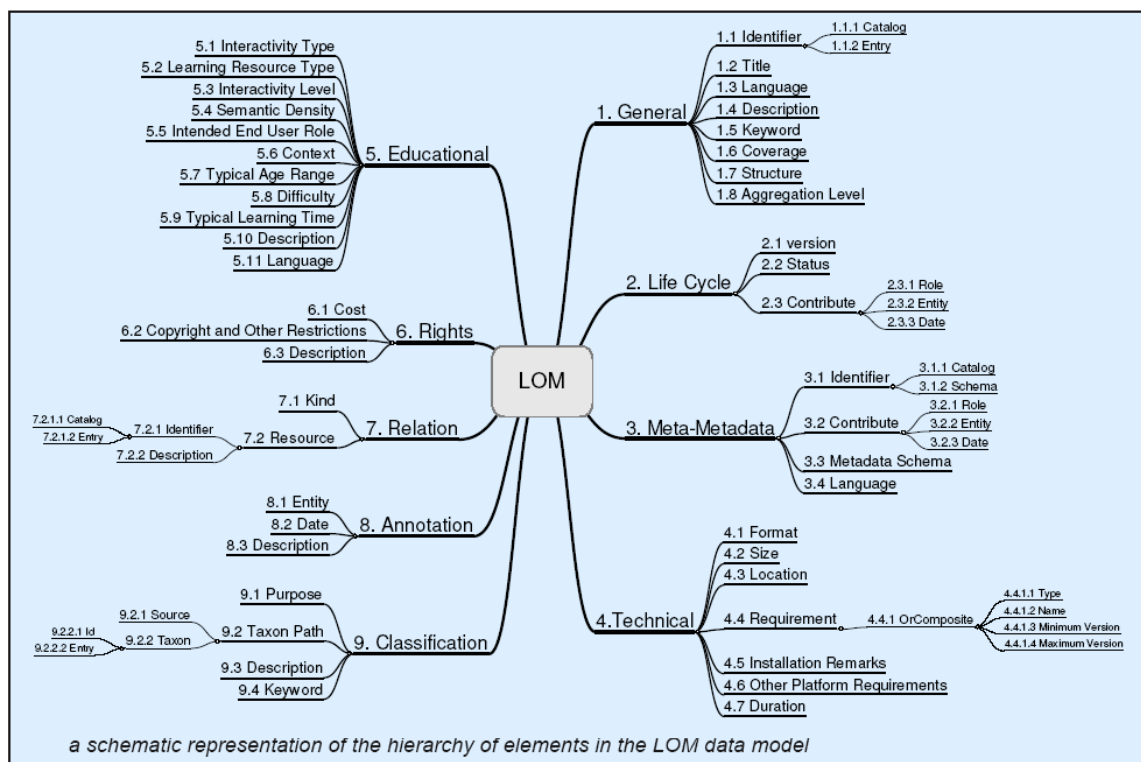


Figure 2.1 A schematic representation of the hierarchy of elements in the LOM data model [Barker, 2005]

In the framework developed in this thesis LOM is used for the description of the learning characteristics of digital resources.

2.2.2. Sharable Content Object Reference Model (SCORM)

ADLNet (Advanced Distributed Learning Network) is an initiative sponsored by the US federal government to “accelerate large-scale development of dynamic and cost-effective learning software and to stimulate an efficient market for these products in order to meet the education and training needs of the military and the nation's workforce of the future.” [SCORM, 2001, 2004]

As part of this objective, ADL produced SCORM (Sharable Content Object Reference Model) [SCORM, 2001, 2004] a set of profiles of standards and specifications for reusable learning content. SCORM addresses interoperability between content and the platforms that deliver the content. It derives from work done by the Aviation Industry CBT Committee (AICC), the IMS Global Learning Consortium and the IEEE Learning Technology Standards Committee, as well as other work in the education and eLearning domain. SCORM [SCORM, 2004] is probably the most important development currently occurring in the area of eLearning standards and specifications. It is widely adopted by Learning Management Systems (LMSs), Learning Content Management Systems (LCMSs), authoring environments, assessment engines and course management systems.

Simply stated, SCORM is a set of specifications for developing, packaging and delivering high quality education and training materials whenever and wherever they are needed. The use of SCORM enables reusability, accessibility and durability of the learning material in technology changes, and interoperability between different e-learning platforms.

These specifications and standards have been bundled into a collection of “technical books.” Each can be viewed as separate books gathered together into a growing library. These technical books (Figure 2.2) are presently grouped under three main topics: the Content Aggregation Model (CAM), the Run-time Environment (RTE) and Sequencing and Navigation (SN).

The **SCORM Content Aggregation Model** further defines a common way by which learning content can be interoperable, interchangeable, reusable and accessible. It defines how learning content is identified, described, aggregated into a “course” and moved between systems. Specifically, the learning resources comprising a learning experience get packaged into a zip file (SCORM package of Package Interchange File (PIF)). This file contains not only the course files, but it also contains an XML file, referred to as the manifest file, describing the course contents and content sequencing.

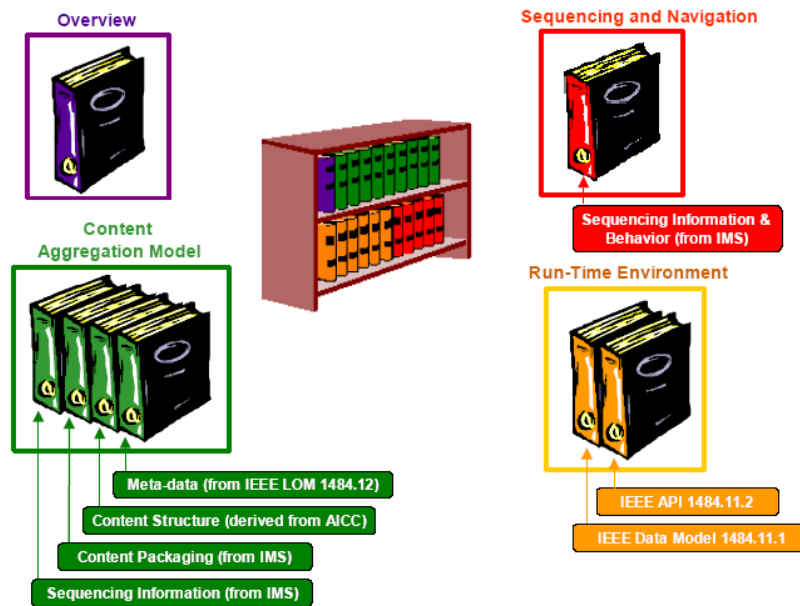


Figure 2.2 SCORM Bookshelf [SCORM, 2004]

The **SCORM Run-Time Environment** defines the means by which SCORM learning content is made interoperable between LMSs. The SCORM Run-Time Environment provides details on how LMSs should launch resources/content, communicate with the content (using a predefined language and vocabulary) and exchange predefined data elements during execution.

In SCORM 2004 version, another specification has been added to SCORM named **Sequencing and Navigation** that describes how SCORM-conformant content may be sequenced through a set of learner-initiated or system-initiated navigation events. The branching and flow of that content may be described by a predefined set of activities, typically defined at design time.

2.2.2.1. SCORM Content Aggregation Model

The SCORM Content Aggregation Model (CAM) [SCORM, 2004] describes the components used in a learning experience, how to package those components for exchange from system to system, how to describe those components to enable search and discovery, and how to define the sequencing rules for the components. The CAM promotes consistent storage, labeling, packaging, exchange and discovery of content; it also provides guidelines and requirements for building content aggregations (e.g., course, lessons, modules, etc). The book contains information on creating content packages, applying metadata to the components in the content package and applying sequencing and navigation details in the context of a content package. We can say that the SCORM Content Aggregation Model represents a learning taxonomy neutral means for designers and implementers of instruction to aggregate learning resources for the purpose of delivering a desired learning experience [SCORM, 2004]. A learning resource is any

representation of information that is used in a learning experience. Learning experiences consist of activities that are supported by electronic or non-electronic learning resources.

One activity in the process of creating and delivering learning experiences involves the creation, discovery and gathering together, or aggregation, of simple assets into more complex learning resources and then organizing the resources into a predefined sequence of delivery. The SCORM Content Aggregation Model supports this process and is made up of the following:

- **Content Model:** Nomenclature defining the content components of a learning experience.
- **Content Packaging:** Defines how to represent the intended behavior of a learning experience (Content Structure) and how to aggregate activities of learning resources for movement between different environments (Content Packaging).
- **Meta-data:** A mechanism for describing specific instances of the components of the content model.
- **Sequencing and Navigation:** A rule-based model for defining a set of rules that describes the intended sequence and ordering of activities. The activities may or may not reference learning resources to be delivered to the learner.

The SCORM Content Model is made up of **Assets**, **Sharable Content Objects (SCOs)** and **Content Organizations**. These are the granularity levels that are defined by SCORM.

An **Asset** is the most basic form of a learning resource. Assets are an electronic representation of media, such as text, images, sound, assessment objects or any other piece of data that can be rendered by a Web client and presented to a learner. An Asset can be described with Asset Meta-data to allow for search and discovery within repositories, thereby enabling opportunities for reuse. The mechanism that provides this model is Content Package.

A **SCO** is a collection of assets that includes a specific launch-able asset that uses the SCORM run-time environment to communicate with an LMS. A SCO represents the lowest level of granularity of a learning resource and it can be used and aggregated with other SCOs in different learning experiences to fulfill different learning objectives. A SCO should be independent of its learning context to improve its reusability. A SCO can be described with SCO Meta-data to allow for search and discovery within repositories, thereby enabling opportunities for reuse. The mechanism that provides this model is Content Package.

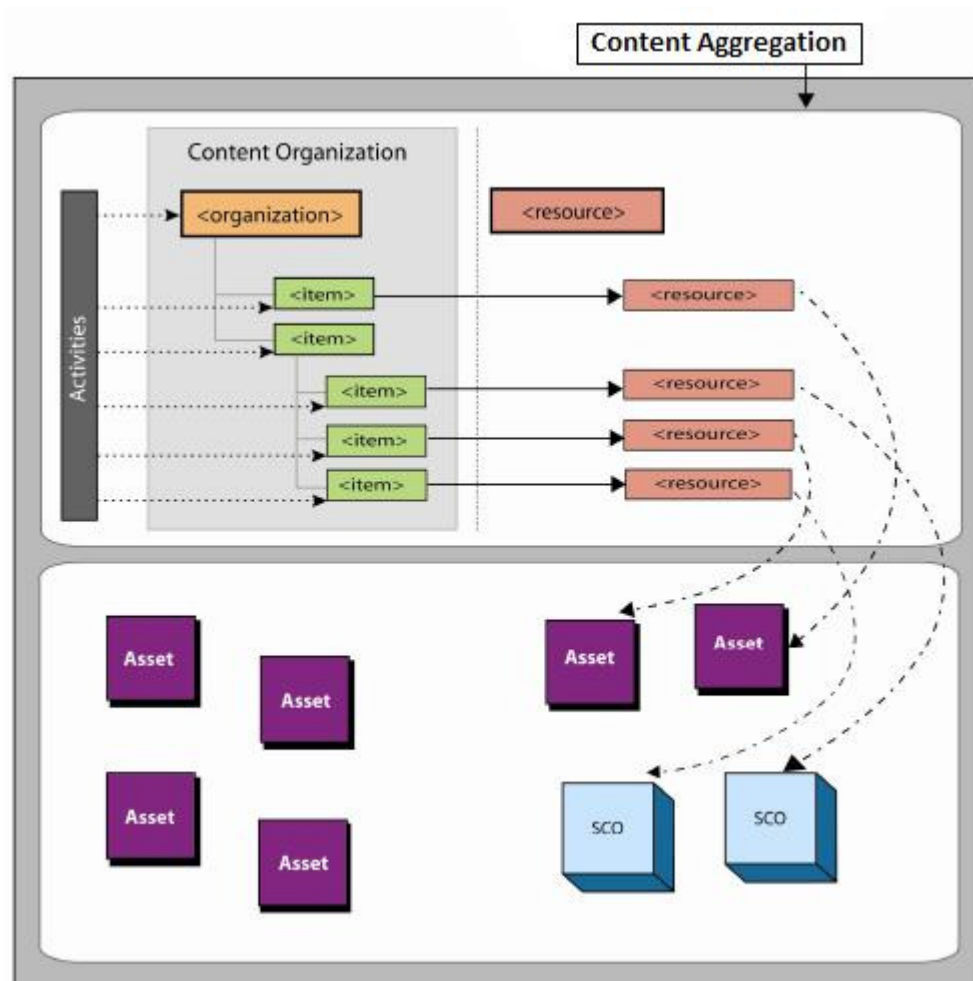


Figure 2.3 Content Organization

A **Content Organization** (Figure 2.3) is a map that represents the intended use of the content through structured units of instruction (Activities). This map shows how Activities relate to one another. The Activities may consist of other Activities and so we may have hierarchical levels of Activities, but this is not a requirement. Activities that do not consist of other Activities (leaf activities) will have an associated learning resource (SCO resource or Asset resource) that is used to perform the activity.

The SCORM Content Model describes the SCORM components used to build a learning experience from learning resources. Once learning content is designed and built, there is a need to make the content available to learners, authoring tools, repositories or Learning Management Systems (LMSs).

In a bid to separate learning content from learning platforms, SCORM makes use of the IMS Content Packaging (IMS CP) specification [IMS CP, 2004] and a profile of the IEEE Learning Object Metadata standard (LOM) [IEEE LOM, 2002]. The combination of IMS CP and IEEE LOM solve the problems of exporting, transporting and importing learning resources as long as the resources are not required to interact with learner

information or other aspects of the learning environment. SCORM Content Packages adheres strictly to the IMS CP Specification and provides additional explicit requirements and implementation guidance for packaging Assets, SCO and Content Organization. Whilst IMS CP permits metadata at every level, SCORM requires that metadata be provided at least for SCOs. Several elements of the IEEE LOM are made mandatory for SCO metadata, they include: technical format; version; status and rights metadata.

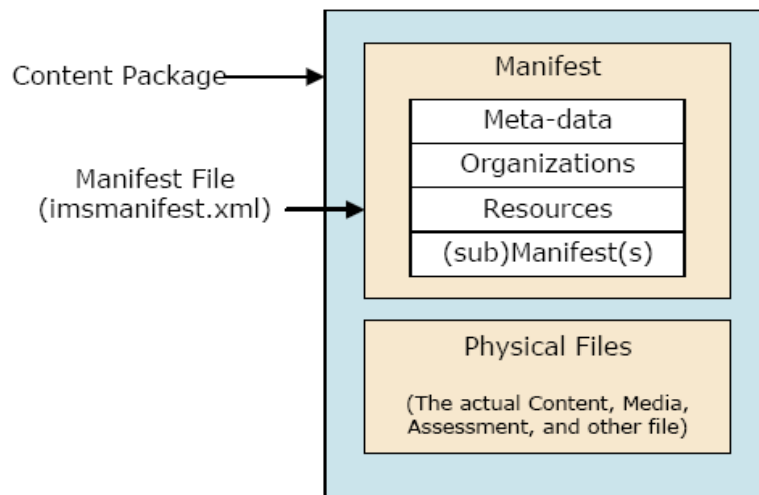


Figure 2.4 Content Package Components

To understand better the components of a SCORM Content Package the standard provides the conceptual diagram illustrated in Figure 2.4 from IMS Content Packaging Specification.

A Content Package contains two major components:

- A special XML document describing the content structure and associated resources of the package called the manifest file (*imsmanifest.xml*). A manifest is required to be present at the root of the content package.
- The content (i.e., physical files) making up the content package.

The manifest is composed of four major sections:

1. **Metadata:** Data describing the content package as a whole.
2. **Organizations:** Contains the content structure or organization of the learning resources making up a stand-alone unit or units of instruction.
3. **Resources:** Defines the learning resources bundled in the content package.
4. **(sub)Manifest(s):** Describes any logically nested units of instruction (which can be treated as stand-alone units).

SCORM recommends that content packages be created as Package Interchange Files (PIFs). A Package Interchange File (PIF) is a binding of the content package components in the form of a compressed archive file (.zip). The PIF contains the *imsmanifest.xml*, all control files and the resources referenced in the content package (those that are local to the PIF, i.e., contained in the content package). The PIF provides a concise Web delivery format that can be used to transport content packages between systems.

It should be noted here that *SCORM does not prescribe the actual size of a SCO or even the size of a whole content aggregation (or unit of learning)*. In addition, although SCORM provides the opportunity for authors to represent the different levels of the structure of learning content hierarchically, it does not specify any particular formal taxonomy, vocabulary, or heavyweight ontology for representing the structure of contents, for example, as a course, module, or lesson. On the other hand, the size of a SCO depends on a synthesis of educational and organizational criteria, such as the scope of instruction, learning objectives, and affordability (in terms of time, cost, human resources, etc.). [Balatsoukas, Morris & O'Brien, 2008]

In the framework developed in this thesis SCORM is used as the delivery means of final learning experiences to eLearning applications.

2.2.3. Educational Modeling Language (EML)/IMS Learning Design (IMS LD)

Nowadays, the need for eLearning systems supporting a rich set of pedagogical requirements has been identified as an important issue in the field of distance learning [Capuano et al., 2005]. Several initiatives take place in order to meet this need. The most important of these initiatives seems to be IMS Learning Design [IMS LD, 2003] that provides a framework to depict pedagogies.

IMS Learning Design specification [IMS LD, 2003] is a development of the Educational Modeling Language [Hummel, Manderveld, Tattersall and Koper, 2004] (designed by the Open University of the Netherlands (OUNL) to enable flexible representation of the elements within online courses; not just the materials but also the order in which activities take place, the roles that people undertake, key criteria for progression, and the services needed for presentation to learners. The learning design specification does not detail how the course material itself is represented but rather how to package up the overall information into a structure that is modeled on a play, with acts, roles (actors) and resources.

The IMS Learning Design specification supports the use of a wide range of pedagogies in online learning. Rather than attempting to capture the specifics of many pedagogies, it does this by providing a generic and flexible language. This language is designed to enable many different pedagogies to be expressed. It allows different pedagogical approaches to be integrated into a single “learning design” where different approaches

may be appropriate for different types of learners. The approach has the advantage over alternatives in that only one set of learning design and runtime tools need to be implemented in order to support the desired wide range of pedagogies.

The IMS Learning Design specifications (Figure 6.4) are structured in three levels. Level A includes activities, roles and environments. Activities (learning activities or support activities) can be grouped into activities structures and executed into specific environments. An environment is formed by learning objects and services provided to users during activity execution. Users are classified into roles (learners, teachers, tutors, etc.). Nowadays, learning objects are educational contents by which learners acquire knowledge and services are functionalities invoked during learning process in order to communicate with tutors or other learners. Level B adds properties (storing information about a single person or a group) and conditions (setting constraints upon the flow of activities) to the first level. Level C adds notifications (mechanism to handle messages passing between users) to the framework.

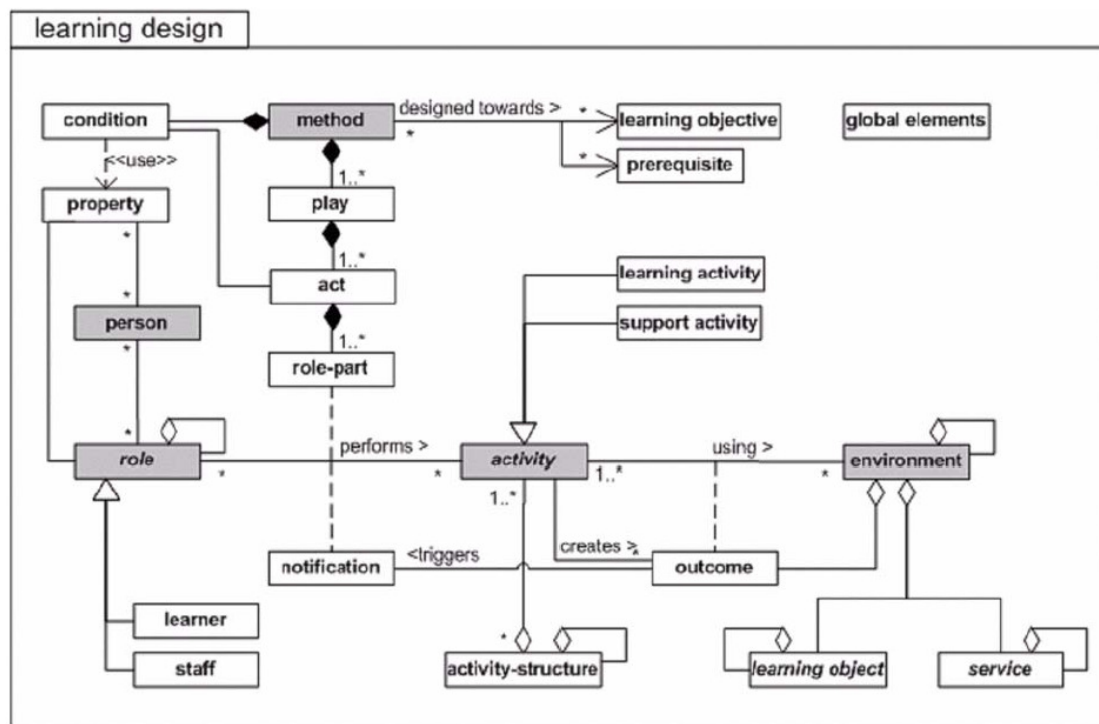


Figure 2.5 Conceptual model for overall IMS Learning Design (from [IMS LD, 2003])

However, although IMS-LD provides a model to personalize the learning experience at run-time using properties and conditions at Level B, the instructional planner has to provide specific learning objects and services, so that learning objects and services are bound to the learning design scenario on design time. This prohibits the construction of “real” personalized learning experiences, where the appropriate learning object according to the learner profile are bound to the decided learning experience on run-time.

The model proposed in this thesis for the construction of abstract training scenarios has the important characteristic that learning objects are not bound in the training scenarios at design time. Instead of that, the pedagogy is separated and independent from the content achieving this way reusability and interoperability of learning designs that can be used from the systems as are, or parts of them for the construction of “real” personalized learning experiences. The term “real” is emphasized here, to indicate that to provide personalized learning experiences, the learner profile should not only affect the selection of a sequence or structure of activities comprising a training scenario that satisfy his/her learning needs (learning objectives, learning style, age, educational level etc.), but also the retrieval of learning objects that are appropriate for him/her. An intelligent component/system can match the knowledge given in the learner profiles and the learning designs in order to build firstly an appropriate activity structure or sequence for the specific learner (learning experience structure or training scenario) and afterwards selecting appropriate learning objects from a digital library for each node (activity) of this structure. This is possible, since the instructional model proposed in this thesis gives the opportunity to specify in each Activity the learning objects’ requirements, instead of binding the learning objects themselves, as IMS Learning Design [IMS LD, 2003] imposes. This instructional model for the construction of abstract training scenarios (learning designs) borrows some elements and ideas from the IMS Learning Design Specification and LOM and its purpose is to overcome the limitations that current eLearning standards and specifications impose.

2.2.1. Metadata Encoding and Transmission Standard (METS)

The Metadata Encoding and Transmission Standard (METS) [METS, 2005a] is a widely-accepted standard designed specifically for digital library metadata that is being developed as an initiative of the Digital Library Federation (DLF) and is being maintained in the Network Development and MARC Standards Office of the Library of Congress. METS is a flexible, but tightly structured, container for packaging together all metadata necessary to describe, navigate and maintain digital objects and the complex links among them:

- **Descriptive metadata:** information relating to the intellectual contents of the object, akin to much of the content of a standard catalogue record: this enables the user of a digital library to find the object and assess its relevance.
- **Administrative metadata:** information necessary for the manager of the electronic collection to administer the object, including information on intellectual property rights and technical information on the object and the files that comprise it.
- **Structural metadata:** information on how the individual components that make up the object relate to each other, including the order in which they should be

presented to the user: for example, how the still image files that comprise a digitized version of a print volume should be ordered.

METS provides an XML document format for encoding metadata necessary for both management of digital objects within a repository and exchange of such objects between repositories (or between repositories and their users). Each type of metadata is described in a separate section in this document, which is linked to its counterparts by internal identifiers. These metadata (any preferred scheme) may be physically stored within the METS XML file, or in external files referenced from within the METS document.

The initiative's Web pages claim that METS has a similar role to that of Information Packages, as defined in the Reference Model for Open Archival Information Systems (Consultative Committee for Space Data Systems, 2002).

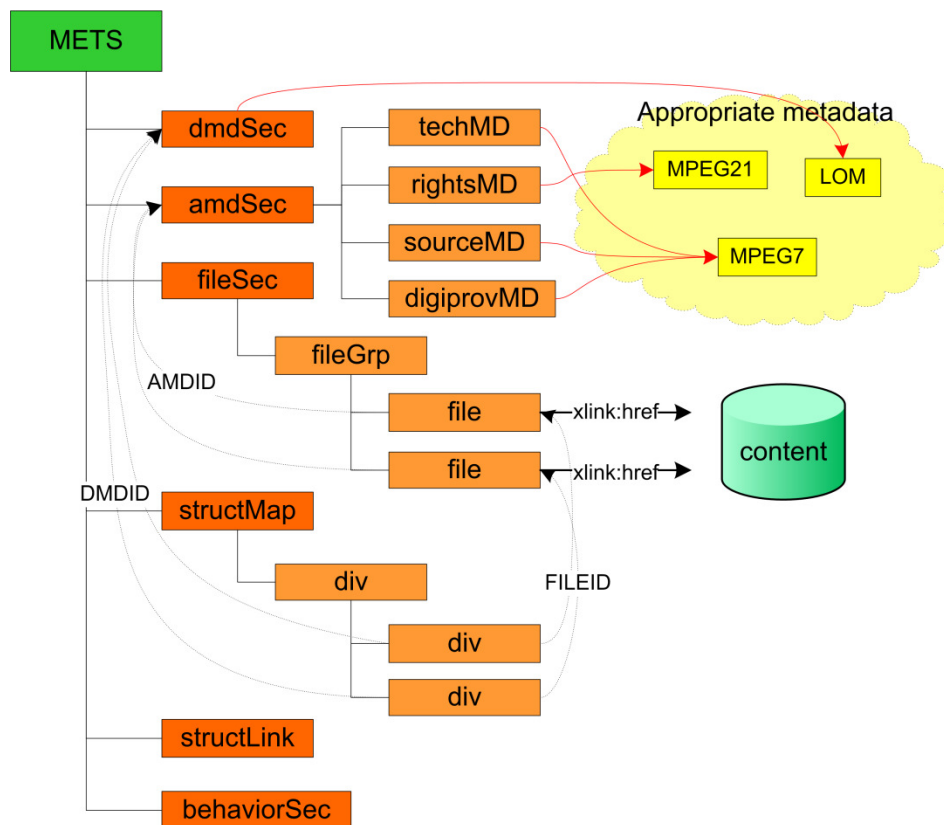


Figure 2.6 The typical structure of a METS document. Any preferred metadata scheme can be used for the descriptive and administrative metadata of the current digital object (e.g. LOM, MPEG7, MPEG21)

A METS document consists of seven major sections, as illustrated in Figure 2.6:

1. **METS Header:** The METS Header contains metadata describing the METS document itself, including such information as creator, editor, etc.
2. **Descriptive Metadata (dmdSec):** The descriptive metadata section may point to descriptive metadata external to the METS document (e.g., a MARC record in an OPAC or an EAD finding aid maintained on a WWW server), or

contain internally embedded descriptive metadata, or both. Multiple instances of both external and internal descriptive metadata may be included in the descriptive metadata section.

3. **Administrative Metadata (amdSec):** The administrative metadata section provides information regarding how the files were created and stored, intellectual property rights, metadata regarding the original source object from which the digital library object derives, and information regarding the provenance of the files comprising the digital library object (i.e., raster/derivative file relationships, and migration/transformation information). As with descriptive metadata, administrative metadata may be either external to the METS document or encoded internally.
4. **File Section (fileSec):** The file section lists all files containing content, which comprise the electronic versions of the digital object. <file> elements may be grouped within <fileGrp> elements, to provide for subdividing the files by object version.
5. **Structural Map (structMap):** The structural map is the heart of a METS document. It outlines a hierarchical structure for the digital library object, and links the elements of that structure to content files and metadata that pertain to each element.
6. **Structural Links (structLink):** The Structural Links section of METS allows METS creators to record the existence of hyperlinks between nodes in the hierarchy outlined in the Structural Map. This is of particular value in using METS to archive Websites.
7. **Behavior:** A behavior section can be used to associate executable behaviors with content in the METS object. Each behavior within a behavior section has an interface definition element that represents an abstract definition of the set of behaviors represented by a particular behavior section. Each behavior also has a mechanism element, which identifies a module of executable code that implements and runs the behaviors defined abstractly by the interface definition.

In this framework METS is used to support multiple-(educational) contexts views of digital objects.

2.2.2. IMS Digital Repository Interoperability Specification (IMS DRI)

The IMS Digital Repositories Interoperability specification [IMS DRI, 2003] purpose is to provide recommendations for the interoperation of the most common repository

functions. These recommendations should be implementable across services to enable them to present a common interface. On the broadest level, this specification defines digital repositories as being any collection of resources that are accessible via a network without prior knowledge of the structure of the collection. Repositories may hold actual assets or the meta-data that describe assets. The assets and their meta-data do not need to be held in the same repository. This specification is intended to utilize schemas already defined elsewhere (e.g. IMS Meta-Data and Content Packaging), rather than attempt to introduce any new schema.

These functions should be implementable across services to enable them to present a common interface. IMS DRI splits services into three categories:

- Access services (resource utilizers): Services with which the end user interacts (e.g. LMS/LCMS, portal)
- Provision services (repositories): Services that make content available, and
- Intermediaries: Services that reside between the above two (e.g. aggregators, brokers)

The DRI specification acknowledges a wide range of content formats and is applicable internationally to both learning object repositories, as well as to other traditional content sources, such as libraries and museum collections.

The functions that are supported are:

- **Search/Expose:** The Search function defines the searching of meta-data for assets “exposed” by repositories. A repository can be searched directly or using an intermediate search engine. XQuery is used when searching meta-data in the IMS XML format, while Z39.50 is used for searching library information.
- **Gather/Expose:** The Gather function allows the aggregation of meta-data from repositories for use in subsequent searches. The Gather function may actively request meta-data from a repository (“pull”) or it can subscribe to a service that notifies the Gather component when meta-data in the repository has been added, deleted or changed (“push”).
- **Submit/Store:** Refers to the way an object is moved to a repository and made accessible. Submit places an object into a repository. Store allows a repository to store the object so that it may be retrieved later.
- **Request/Deliver:** These functions allow a system user to request learning objects or other resources located with the Search function. The Search function returns repository object identifiers as a list of locations or as a method, such as a

Digital Object Identifier (DOI), that resolves to one or more locations. The location returned by Search resolves to a URL that can then be used to Request the object. The protocol used to deliver a requested learning object depends on the object type.

- **Alert/Expose:** These functions provide a method for notifying interested parties of any changes made to content stored in a repository or repository system. They are not considered in Phase 1 of the DRI specification.

The DRI specification outlines use cases that illustrate the set of roles adopted most commonly by the users (including both people and software) of the e-learning application, digital repositories, and information services. The Role undertaken at any time is dependent on the context. The users may adopt more than one role over the life of an event including interactions with repositories.

The roles defined in IMS DRI are the following [IMS DRI, 2003]:

- **Learner:** A Learner is defined as a person following a learning path and/or enrolled in a course or training program. The Learner can be actively engaged in a learning activity delivered as part of an e-learning application. From within the application, a Learner may need to discover resources that are required to complete an assignment, or may facilitate the completion of a learning task—a discussion, quiz, group project, or chat are examples of learning tasks that happen within an e-learning environment. The Learner may be affiliated with either a learning application or a learning information service, acting on his/her own behalf in the pursuit of knowledge. Once the Learner leaves the e-learning application, his/her primary role may change from a Learner to an Infoseeker.
- **Creator:** A Creator is defined as a person responsible for the creation of learning objects or other resources, or the construction of learning paths, courses, or learning programs. A Creator may be an independent content developer, content publisher, instructional designer, manager, instructor, or tutor that may be collecting, constructing, and sequencing content for delivery to a Learner. A Creator is someone within an e-learning environment or information services.
- **Infoseeker:** An Infoseeker is defined as a person seeking to obtain information through the discovery of resources. A Learner may become an Infoseeker in order to complete tasks during a course or training program. A Creator may also become an Infoseeker, discovering and accessing resources of all kinds, including learning objects. An Infoseeker does not have to be inside an e-learning system, and may be accessing resources from a library or other information services located within the enterprise.

- **Agent:** An Agent is defined as an intelligent software application that carries out tasks directly on behalf of a Learner, Creator, or Infoseeker. The Agent could be engaged from inside the e-learning application, digital repository, or information services. The results of the Agent may be processed programmatically or with intervention from the Learner, Creator, or Infoseeker.

IMS DRI recommendations are implemented in this thesis upon repositories at each level to enable them to present a common interface.

2.2.3. Multimedia Content Description Interface (MPEG7)

The MPEG7, formally named “Multimedia Content Description Interface”, is an ISO/IEC standard (ISO/IEC 15938) developed by MPEG (Moving Picture Experts Group). MPEG7 offers a comprehensive set of audiovisual Description Tools to guide the creation of audiovisual content descriptions, which will form the basis for applications that provide the needed effective and efficient access to audiovisual content [Chang, Sikora and Puri, 2001; Manjunath, Salembier and Sikora, 2002]. The MPEG7 audiovisual content descriptions may be created either manually or automatically and, after being stored, can be accessed by different applications such as querying, browsing and filtering.

The main elements of the MPEG7 standard are the Description Tools, the Description Definition Language (DDL) and the System Tools.

1. **Description Tools:** They guide the audiovisual content description process. The MPEG7 Description Tools include the **Datatypes**, the **Descriptors (D)**, and the **Description Schemes (DS)**.

A **Datatype** is not specific to the multimedia domain and is essentially a reusable basic type or structure employed by multiple Descriptors and Description Schemes.

A **Descriptor (D)** represents a multimedia feature and defines the syntax and the semantics of each feature representation. A Feature is a distinctive characteristic of the data, which signifies something to somebody. It is possible to have several descriptors representing a single feature, in order to address different relevant requirements.

A **Description Scheme (DS)** provides descriptive information and specifies the structure and the semantics of the relationships between its components, which may be both Descriptors and Description Schemes.

2. **Description Definition Language (DDL):** It defines the syntax of the MPEG7 Description Tools and allows the creation of new Description Schemes and,

possibly, Descriptors. In addition, the MPEG7 DDL allows the extension and modification of existing Description Schemes.

3. **System Tools:** They support a binary coded representation for efficient storage and transmission, transmission mechanisms (both for textual and binary formats), multiplexing of descriptions, synchronization of descriptions with content, management and protection of intellectual property in MPEG7 descriptions, etc.

The MPEG7 Standard consists of the following 8 parts:

1. **MPEG7 Systems.** It is currently comprised of the binary format for encoding MPEG7 descriptions and the terminal architecture [MPEG7, 2001a].
2. **MPEG7 Description Definition Language.** It is the language used for the definition and possible extension of the MPEG7 Description Tools [MPEG7, 2001b].

The MPEG7 DDL is based on the XML Schema Language [Fallside, 2001; Thompson et al., 2001; Biron and Malhotra, 2001]. As the XML Schema Language has not been designed specifically for audiovisual content descriptions, certain extensions (in the form of XML Schema types) have been added to the MPEG7 DDL. As a consequence, the DDL can be broken down into the following logical normative components:

- The XML Schema structural language components [Thompson et al., 2001], which include the basic building blocks of XML Schema (simple and complex types, attributes etc.);
 - The XML Schema datatype language components [Biron and Malhotra, 2001], where the capability of defining Datatypes is provided;
 - The MPEG7 specific extensions [MPEG7, 2001b], which include the XML Schema extensions added in the DDL in order to cover all the needs of the audiovisual domain.
3. **MPEG7 Visual.** It includes the Description Tools (both elementary and sophisticated) describing (only) Visual descriptions. The MPEG7 Visual Description Tools cover the basic visual features: Color, Texture, Shape, Motion, Localization and Face Recognition [MPEG7, 2001c].
 4. **MPEG7 Audio.** It provides the Description Tools dealing with (only) Audio descriptions. The MPEG7 Audio provides, in conjunction with the Multimedia Description Schemes part of the standard, structures for describing audio content. Using these structures one can define both a set of low-level

Descriptors, for audio features that cut across many applications (e.g., spectral, parametric, and temporal features of a signal), and high-level Description Tools that are more application-specific. The high-level tools include general sound recognition and indexing Description Tools, instrumental timbre Description Tools, spoken content Description Tools, an audio signature Description Scheme and melodic Description Tools to facilitate query-by-humming [MPEG7, 2001d].

5. **MPEG7 Multimedia Description Schemes**, (also called **MDS**). It includes the set of Description Tools (Descriptors and Description Schemes) for generic features and multimedia descriptions [MPEG7, 2001e]. Generic features are used in both audio and visual descriptions, and are therefore “generic” to all media (e.g. “vector”, “time”, textual description tools, controlled vocabularies, etc.). Complex Description Tools are used whenever more than one medium needs to be described (e.g. audio and video) and can be classified into 5 categories (see):
 - a. **Content Description**. It includes Description Tools for the representation of perceivable information. The Content Description Elements of the MPEG7 MDS are the description mechanism for the structure and the semantics of the audiovisual content. The structural tools describe the structure of the audiovisual content in terms of video segments, frames, still and moving regions and audio segments. The semantic tools describe the objects, events, and notions from the real world that are captured by the audiovisual content.
 - b. **Content Management**. It captures information about the media features, the creation and the usage of the audiovisual content. The Content Management Elements of the MPEG7 MDS allow the description of the life cycle of the content, from content creation to consumption. They provide Creation, Media and Usage information about the audiovisual content.
 - c. **Content Organization**. It includes Description Tools for the representation, analysis and classification of several audiovisual items. The Content Organization Elements of the MPEG7 MDS allow organizing and modeling collections of audiovisual content and descriptions.
 - d. **Navigation and Access**. It includes Description Tools for the specification of summaries and variations of the audiovisual content. The Navigation and Access Elements of the MPEG7 MDS facilitate browsing and retrieval of audiovisual content by defining summaries, partitions and decompositions, and variations of the audiovisual material.

- e. **User Interaction.** It allows the description of user preferences and usage history pertaining to the consumption of the multimedia material. The User Interaction Elements of the MPEG7 MDS describe user preferences and usage history pertaining to the consumption of the multimedia material. This allows matching between user preferences and MPEG7 content descriptions in order to facilitate personalization of audiovisual content access, presentation and consumption.

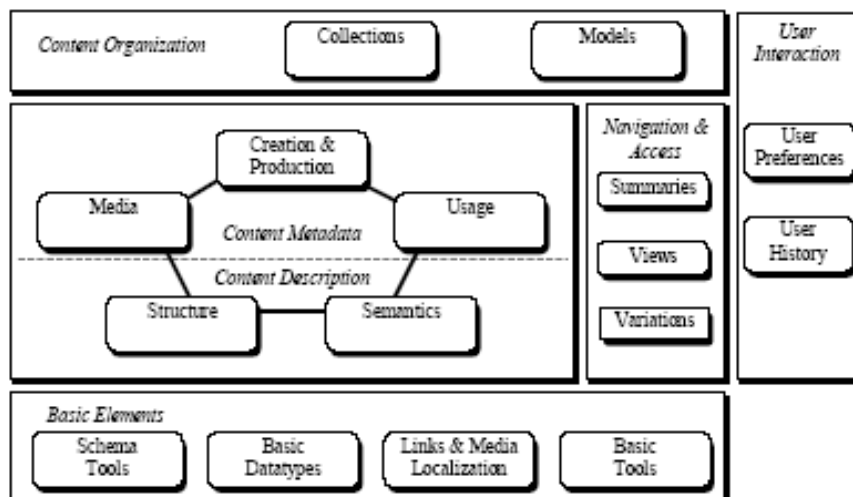


Figure 2.7 Overview of the Multimedia Description Scheme (MDS) description tools [MPEG7, 2001e]

6. **MPEG7 Reference Software.** It consists of a software implementation of relevant parts of the MPEG7 Standard with normative status, the eXperimentation Model (XM). The eXperimentation Model (XM) software is the simulation platform for the MPEG7 Descriptors (Ds), Description Schemes (DSs), Classification Schemes (CSs), and the Description Definition Language (DDL). XM applications are either server (extraction) applications or client (search, filtering and/or transcoding) applications. The simulation platform defines also some non-normative components which include some procedural code that is executed on the data structures forming, together with the procedural code, the applications.
7. **MPEG7 Conformance Testing.** It provides guidelines and procedures for testing conformance of MPEG7 implementations.
8. **MPEG7 Extraction and Use of Descriptions.** It consists of informative material (in the form of a Technical Report) about the extraction and use of some of the Description Tools, providing additional insight into the MPEG7 Reference Software implementation as well as alternative approaches.

2.3. Personalization in eLearning

It is becoming more and more apparent that “one size fits all” solutions are no longer enough to satisfy learners’ educational needs [Arapi et al., 2007]. Different learners have different learning styles, educational levels, previous knowledge, technical and other preferences and all these are parameters that affect the learning function outcome. Learners expect from systems a “personal trainer” and not a “classroom” behaviour, where their personality and needs are known and taken into account. Moreover, the proliferation of the Internet and the wealth of content in Learning Object Repositories call for flexible solutions where content is not strictly bound with the learning plan but could be retrieved at run-time and ideally from many sources according to the learner needs (open corpus). Adaptive eLearning Systems have emerged in order to address the above needs and provide effective personalisation services [Dagger et al., 2004; Paramythis and Loidl-Reisinger, 2004].

2.3.1. Important parameters that affect personalization in eLearning

A learning experience can be considered as a learning plan with associated learning material (or in a broader view with services) that a Learner exploits in order to fulfill his/her learning goals. Ideally, both the construction of the learning plan and its association with appropriate learning material should be affected by the Learners’ educational needs and preferences. There are several benefits of thinking about and trying to understand learning preferences¹:

- people learn most effectively when the strategies used are closely matched with their preferred learning style
- sometimes we can improve our learning by knowing what our strengths are and then doing more of what we're good at
- often we can improve our learning by knowing what our weakness are and trying to enhance our skills in these areas
- different situations and learning environments require different learning strategies, so it's best to have a large repertoire from which to draw.

But which are these educational needs and preferences that essentially should be considered as input parameters in personalization processes and what is their role in the construction of a learning plan and/or its binding with appropriate learning resources? There are a number of factors that can influence the extent of learning. Based on bibliography and previous research works, we argue that the following parameters are

¹ <http://www.sdc.uwo.ca/learning/index.html?styles>

positively affecting the efficiency of learning processes when taken into account and we describe each of them in the following sections:

- Learning Style
- Learner Goals/Objectives
- Previous Knowledge
- Educational Level and Difficulty
- Technical Preferences
- Other Preferences (e.g. language etc.)

2.3.1.1. Learning Style

With simple words, learning style (or learning preference) is the way a Learner tends to learn best. It involves Learner's preferred method of taking in, organizing, and making sense of information. Learning styles do not tell us about a person's abilities or intelligence, but they can help us understand why some tasks seem easier for us than others.

There are several definitions of “learning styles” in the literature [Karagiannidis & Sampson, 2004]. Learning styles can be generally described as “an individual's preferred approach to organizing and presenting information” [Riding & Rayner, 1998]; “the way in which learners perceive, process, store and recall attempts of learning” [James & Gardner, 1995]; “distinctive behaviors which serve as indicators of how a person learns from and adapts to his environment, and provide clues as to how a person's mind operates” [Gregoric, 1979]; “a gestalt combining internal and external operations derived from the individual's neurobiology, personality and development, and reflected in learner behavior [Keefe & Ferrell, 1990], “the attitudes and behaviors which determine an individual's preferred way of learning” [Honey et al, 1992]. For example, a student who prefers practical experience may prefer to begin writing code immediately in order to learn a new programming language, whereas another may prefer reading up and studying the new language prior to writing any code.

Education research and practice have demonstrated that learning can be enhanced when the instructional process accommodates the various learning styles of students [Buch & Bartley, 2002; Manochehr, 2006]. Thus, learning and cognitive styles have generated a significant amount of interest because of the influence they can have on the effectiveness of delivery of teaching and pedagogical materials for a Learner [iClass Project, 2006; Goold and Rimmer, 2000; Griggs, 1991a; Lang et al., 1999; Montgomery and Grout, 1998; Renniger et al., 1992; Warren and Dziuban, 1997; Wilson, 1996]. This has been also

recently proven by the evaluation results of the 3DE Project (5th Framework Programme), where in a panel group of 160 people 98% improve better when their Learning Style was taken into account than without Learning Style [D12 “3DE Assessment & Evaluation”].

There are several approaches of learning styles in bibliography. The most popular of them are presented by [Karagiannidis & Sampson, 2004] and gathered in Table 2.1. However, while there is plenty of research on learning style, there does not seem to be any agreement or acceptance of any one theory [Bruen et al., 2002]. Most Learners are unaware of their own learning style but are vaguely aware of what they feel comfortable with, and learn more from, certain activities than others [Honey et al, 1992]. Thus, in most learning style approaches, a corresponding assessment instrument is provided, in order to be able to detect the learning style of a learner (Table 2.1). This assessment instrument in each learning style approach practically corresponds to an appropriate questionnaire that has been constructed to reveal the Learner’s dominant learning style(s) according to the current approach, after its completion by the Learner.

Table 2.1 Several approaches of Learning Styles [Karagiannidis & Sampson, 2004]

Learning style approach	Learners’ Categorization	Assessment Instrument
Kolb Learning Style Inventory [Kolb, 1984; Kolb A. 1985]	Divergers (concrete, reflective), Assimilators (abstract, reflective), Convergers (abstract/active), Accommodators (concrete/active)	Learning Style Inventory (LSI), consisting of 12 items in which subjects are asked to rank 12 sentences describing how they best learn.
Dunn and Dunn – Learning Style Assessment Instrument [Dunn & Dunn, 1978; Dunn & Dunn, 1999]	Environmental, Emotional, Sociological, Physical factors.	(i) Learning Style Inventory (LSI) designed for children grade 3-12; (ii) Productivity Environmental Preference Survey (PEPS) – adult version of the LSI containing 100 items
Felder-Silverman – Index of Learning Styles [Felder & Silverman, 1988; Felder, 1996]	Sensing-intuitive, Visual-verbal, Indicative-deductive, Activerreflective, Sequential-global	Soloman and Felder questionnaire, consisting of 44 questions
Riding – Cognitive Style Analysis [Riding & Cheema, 1991; Riding, 1994]	Wholists-Analytics, Verbalisers-Imagers	CSA (Cognitive Styles Analysis) test, consisting of three sub tests based on the comparison of the response time to different items
Honey and Mumford – Learning Styles Questionnaire [Honey & Mumford, 1992]	Theorist, Activist, Reflector, Pragmatist	Honey & Mumford’s Learning Styles Questionnaire (LSQ), consisting of 80 items with true/false answers
Gregoric-Mind Styles and Gregoric Styles Delineator [Gregoric, 1982; Gregoric, 1979]	Abstract Sequential, Abstract Random, Concrete Sequential, Concrete Random	Gregoric Style Delineator containing 40 words arranged in 10 columns with 4 items each; the learner is asked to rank the words in terms of personal preference

McCarthy – 4 Mat System [McCarthy, 1980; McCarthy, 1997]	Innovative, Analytic, Common sense, Dynamic	-
Gardner – Multiple Intelligence Inventory [Gardner 1993a; Gardner, 1993b]	Linguistic, Logical-mathematical, Musical, Bodily-kinesthetic, Spatial, Interpersonal, Intrapersonal	an instrument consisting of 8 questions
Grasha-Riechmann – Student Learning Style Scale [Hruska-Riechmann & Grasha, 1982; Grasha, 1996]	Competitive-Collaborative, Avoidant-Participant, Dependent-Independent.	90 items self-report inventory measuring the preferences of both high school and college students
Hermann – Brain Dominance Model [Herrmann, 1982; Hermann, 1995]	Quadrant A (left brain, cerebral), Quadrant B (left brain, limbic), Quadrant C (right brain, limbic), Quadrant D (right brain, cerebral)	120 questions that refer to four profile preferences codes corresponding to each quadrant
Mayers-Briggs – Type Indicator [Myers & Kirby, 1994]	Extroversion, Introversion, Sensing, Intuition, Thinking, Feeling, Judgement, Perception	(i) MBTI (Myers-Briggs Type Indicator), (ii) Kiersey Temperament Sorter I, and (iii) Kiersey Character Sorter II

Learning style models can be categorized in different ways. Curry [1983] presents learning styles models through an onion metaphor, consisting of three basic layers which categorize learners in terms of instructional preferences (outermost layer), information processing (middle layer) and personality (innermost layer). Social interaction, a fourth layer placed between Curry's two outer layers, was proposed by [Claxton and Murrell, 1987]:

- instructional & environmental preferences (e.g. Dunn and Dunn)
- social interaction models (e.g. Perry: how students develop through different intellectual maturation levels as they go to college)
- information processing models (e.g. Kolb, Honey and Mumford)
- personality models (e.g. Myers and Briggs).

The learning styles can also, according to Riding and Rayner [1998], be categorized as following:

- the learning process – based on experimental learning (e.g. Kolb, Honey and Mumford)
- the learning process –based on orientation to study (e.g. Entwistle: deep/strategic/surface)
- instructional –preference (e.g. Dunn and Dunn)

- cognitive skills and learning strategy development (e.g. Reinert: visualization/verbal symbols/sounds/emotional feelings)

Learning has mainly to do with how learners perceive and process information [Sarrikoski, 2000]. So, if we want to create the most suitable learning experiences for learners' learning styles, we shouldn't measure the whole personality or what is the most suitable environment for each learner but we should concentrate on the learning process, information processing and experimental learning.

Towards this end, Kolb's, Honey and Mumford learning style models are the most relevant since they are categorized as being information processing model types or more specifically information processing models based on experiential learning [Sarrikoski, 2000]. The other models categorize the learner on the basis of less relevant aspects to learning (e.g. senses and the environmental factors).

In the next subsections the well known Kolb's and Honey and Mumford learning style models are described. Here we should stress that the personalization framework presented in this thesis is flexible enough to accommodate any learning style taxonomy. We have chosen to describe those learning style approaches, because they are widely used in the eLearning community and according to the reasons presented earlier we believe that they could be effectively used with ICT since they are information processing models.

2.3.1.1.1 Kolb's learning styles

One of the most well known and widely used learning style theories has been developed by Kolb in 1970's. His theory is based on experimental learning paradigm and theories by Dewey, Piaget, Jung and Lewin.

In the model developed by Kolb, learning styles are measured on two perpendicular axes (continuums):

- 1) **Processing Continuum** connecting Active Experimentation (AE) with Reflective Observation (RO) and represents our approach to a task (preferring to do or watch), and
- 2) **Perception Continuum** linking Abstract Conceptualization (AC) with Concrete Experience (CE) and reflecting our emotional response to the situation (preferring to think or feel).

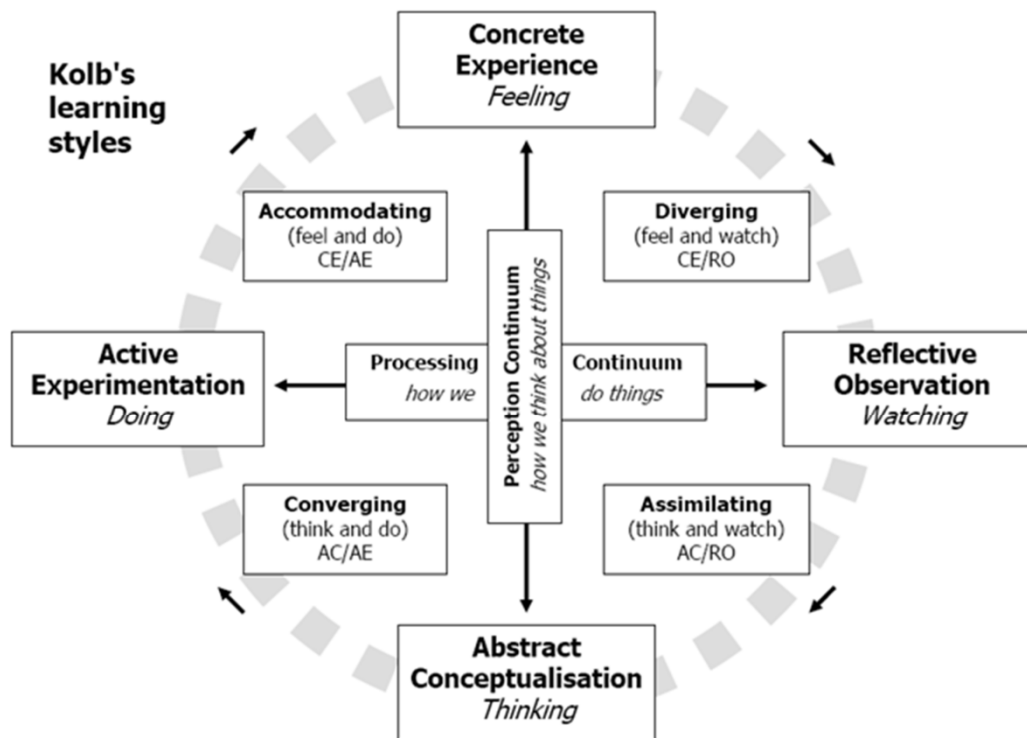


Figure 2.8 Kolb's learning styles [Alan Chapman 2005-6 adaptation and design]

He stated that learning styles could be seen on a continuum running from:

- **concrete experience:** being involved in a new experience
- **reflective observation:** watching others or developing observations about own experience
- **abstract conceptualization:** creating theories to explain observations
- **active experimentation:** using theories to solve problems, make decisions

The quadrants defined by those continuums are Kolb's four learning types [Kolb 1984; Kolb Learning Style Indicator; Kolb's Learning Styles; Leino and Leino 1996; O'Connor 2000]. These are²:

1. **Diverging (feeling and watching - CE/RO)** - 'These people are able to look at things from different perspectives. They are sensitive. They prefer to watch rather than do, tending to gather information and use imagination to solve problems. They are best at viewing concrete situations several different viewpoints. Kolb called this style 'Diverging' because these people perform better in situations that require ideas-generation, for example, brainstorming. People

² <http://www.edgeofadventure.co.uk/mbbs22/forums/get-attachment.asp?attachmentid=419>

with a Diverging learning style have broad cultural interests and like to gather information. They are interested in people, tend to be imaginative and emotional, and tend to be strong in the arts. Divergers prefer to work in groups, to listen with an open mind and to receive personal feedback.

2. **Assimilating (watching and thinking - AC/RO)** - The Assimilating learning preference is for a concise, logical approach. Ideas and concepts are more important than people. These people require good clear explanation rather than practical opportunity. They excel at understanding wide-ranging information and organizing it a clear logical format. People with an Assimilating learning style are less focused on people and more interested in ideas and abstract concepts. People with his style are more attracted to logically sound theories than approaches based on practical value. People with this learning style are important for effectiveness in information and science careers. In formal learning situations, people with this style prefer readings, lectures, exploring analytical models, and having time to think things through.
3. **Converging (doing and thinking - AC/AE)** - People with a Converging learning style can solve problems and will use their learning to find solutions to practical issues. They prefer technical tasks, and are less concerned with people and interpersonal aspects. People with a Converging learning style are best at finding practical uses for ideas and theories. They can solve problems and make decisions by finding solutions to questions and problems. People with a Converging learning style are more attracted to technical tasks and problems than social or interpersonal issues. A Converging learning style enables specialist and technology abilities. People with a Converging style like to experiment with new ideas, to simulate, and to work with practical applications.
4. **Accommodating (doing and feeling - CE/AE)** - The Accommodating learning style is 'hands-on', and relies on intuition rather than logic. These people use other people's analysis, and prefer to take a practical, experiential approach. They are attracted to new challenges and experiences, and to carrying out plans. They commonly act on 'gut' instinct rather than logical analysis. People with an Accommodating learning style will tend to rely on others for information than carry out their own analysis. This learning style is prevalent and useful in roles requiring action and initiative. People with an Accommodating learning style prefer to work in teams to complete tasks. They set targets and actively work in the field trying different ways to achieve an objective.

Traditional teaching in classrooms and learning through textbooks is concentrated in quadrant 2, appealing to assimilators who prefer reflective observation and abstract conceptualization, and employ deductive reasoning. Kolb argues that all learning styles

can be addressed by progressing through a repetitive cycle of reflective observation, abstract conceptualization, active experimentation, and concrete experience. Using this approach, the higher levels of Bloom's taxonomy of educational objectives can be reached.

2.3.1.1.2 Honey & Mumford's learning styles

Honey and Mumford have developed Kolb's ideas. Honey & Mumford's four key styles have a mutually corresponding relationship with Kolb's model in which the learning styles are a product of combinations of the learning cycle stages:

- Activist = Accommodating
- Reflector = Diverging
- Theorist = Assimilating
- Pragmatist = Converging

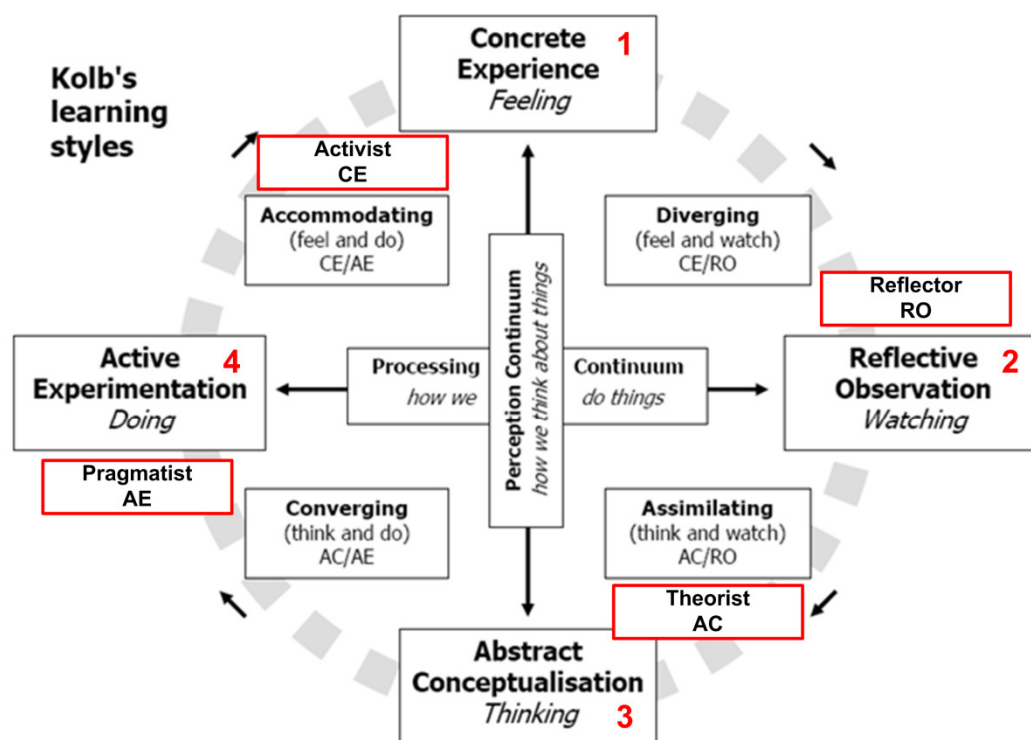


Figure 2.9 Honey & Mumford's learning styles and their relation to Kolb's learning styles

Activists (CE) 'Experiencing'

'here and now', gregarious, seek challenge and immediate experience, open-minded, bored with implementation

Activists like new experiences; they enter the cycle at the experiences stage. They are usually willing to try anything and tend to be enthusiastic about new ideas. They learn best when there are new experiences and problems available, especially where these are short-term results to be gained. They like other people around to bounce ideas off.

Activists tend to leave manuals still in their wrapping - they try things out to see what happens rather than have somebody tell them.

They learn least when learning is passive and involves a great deal of reading or listening to a tutor. They will be more comfortable with more formal learning methods if they have had the opportunity for hands-on experience prior to any seminar or presentations.

Reflectors (RO) 'Evaluating'

'stand back', gather data, ponder and analyze, delay reaching conclusions, listen before speaking, thoughtful

Reflectors like to consider experiences in detail. They tend to be more cautious than activists. While to an activist the experience is everything and evaluation takes second place, to a reflector experiences should be short and then there needs to be plenty of time for evaluation.

Reflectors learn best when they are encouraged to evaluate an activity and then given plenty of time to think about what happened before proceeding to the next task. They learn least when activity follows activity with little or no time to consolidate their thoughts.

Theorists (AC) 'Conceptualizing'

think things through in logical steps, assimilate disparate facts into coherent theories, rationally objective, reject subjectivity and flippancy

Theorists like to integrate their observations and experiences into a logical, conceptual framework. They want to know how and why it happened this way. They respond to being given all the details first and then they will try it. In this respect they are the exact opposite of the activist who cannot wait to get his or her hands on the task.

Theorists learn best when they can see how the task fits into the whole and they are directed to the theoretical background to events. They learn least when they are forced to undertake the task before they have understood the implications and theoretical background. They need a clear mental picture before actually undertaking a task.

Pragmatists (AE) ‘Experimenting’

seek and try out new ideas, practical, down-to-earth, enjoy problem solving and decision-making quickly, bored with long discussions

Pragmatists want to try out new theoretical ideas but in practice/simulated activities before moving on to the real thing. They are experimenters. They tend to be very practical people who can make a link between theory and practice but wish to be sure, via experimentation, that their ideas are correct before undertaking the task proper.

Pragmatists learn best when they can concentrate on practical issues and they can see the link between theory and practice. They learn least when they cannot see the relevance between the theory and an immediate practical need.

Though we may have several learning styles it is the dominant one that determines where we enter the cycle (Figure 2.9).

- An activist begins at 1 and proceeds through 2-3-4 and back to 1.
- A reflector begins at 2 and proceeds through 3-4-1 and back to 2.
- A theorist begins at 3 and proceeds through 4-1-2 and back to 3.
- A pragmatist begins at 4 and proceeds through 1-2-3 and back to 4.

Learning styles can affect both the construction of the learning plan and the selection of learning objects in a learning experience and its formation is dependent on the approach/taxonomy that is used in a specific environment for the definition of learning styles. For example let's consider the case that the taxonomy proposed in [Chen & Mizoguchi, 1999] is used defining four types of learning styles {general to specific, specific to general, principle-oriented, example-oriented}. If a Learner's learning style is general to specific then the learning plan should be organized in a manner that the Learner in a learning experience will start with general concepts and end with more specific concepts. If the learning experience is intended for a Learner that is example oriented we expect to see material that contains many examples and that is very descriptive in its nature (e.g. images, videos).

Stash [2007] proposes the following instructional strategies for six well known learning styles approaches (Table 2.2):

Table 2.2 Recommendations for implication of learning styles in pedagogy [Stash, 2007]

Learning styles	Recommendation for pedagogy
Auditory	More audio material
Visual/Visualizer/ Imager	More pictorial material, such as diagrams, charts, graphs (possibly plus text)
Verbal/Verbalizer	More textual material (possibly plus audio)
Tactile/Kinesthetic	Interactive elements: puzzles, drag & drop fill-ins, small games
Global/(W)holist	Breadth-first structure of the material (possibly guided navigation at each level)
Analytic/Sequential/ Serialist	Depth-first structure of the material
Field-dependent/Un- directed	Breadth-first structure of the material, guided navigation, route suggestion with instructional cues or background colors, context highlighting Illustration of the ideas with visual materials Graphic visualization: main menu, concept map or graphic path indicator Advance organizer Program control Providing maximum feedback Providing social features
Field-independent/ Reproduction- oriented	Depth-first structure of the material or navigational freedom Index, search option Learner control Provide individual environment
Activist/Active/ Extravert	Activity-oriented approach: showing content of activity and links to example, theory, exercise
Reflector/Reflective/ Introvert	Example-oriented approach: showing content of example and links to theory, exercise, activity
Pragmatist	Exercise-oriented approach: showing content of exercise and links to example, theory, activity
Theorist	Theory-oriented approach: showing content of theory and links to example, exercise, activity
Converger	Abstract information
Diverger	Concrete information
Assimila- tor/Meaning-oriented	Theory-based information
Accomodator/Appli- cation-oriented	Application-based information
Sensing/Sensor	Examples before expositions
Intuitive	Expositions before examples
Judger	Rich media, such as pictures, tables, and diagrams
Perceiver	Lean media (without the integrative use of pictures, tables and diagrams)

2.3.1.2. Learner Goals/Objectives

Taking goal priorities and goal dependencies into account when deciding what to learn and how to coordinate multiple learning strategies improves the effectiveness of learning in a system with multiple goals [Cox, 1993; Cox and Ram, 1994; Gratch, DeJong, and

Chien, 1994; Hadzikadic and Yun, 1988; Ram and Leake, 1995]. Several models include learning goals as an explicit part of their formulation of the learning process, information search, hypothesis evaluation, and other aspects of learning; to select and combine learning strategies; to guide and to learn about the reasoning process itself; and to model active learning in educational context. In any goal-driven system, the influence of goals on the performance task also influences what is learned, by determining the focus of processing or changing the context in which learning is performed [Barsalou, chap. 17]. Learning strategies, represented as methods for achieving learning goals, can be chained, composed, and optimized, resulting in learning plans that are created dynamically and pursued in a flexible manner [Ram and Leake, 1995].

The combinatorics of learning require the selection of learning methods that are appropriate to particular kinds of problems, and goal orientation clearly affects the result of learning. This convergence of evidence from both psychological studies and from computational complexity analysis in machine learning suggests a hypothesis about the control of learning: Goals about what would be desirable to learn are central to making required decisions about what and how to learn. [Ram and Leake, 1995].

Action psychology [Ram and Leake, 1995] is based on the ideas that human behavior is directed towards the accomplishment of goals, that is directed by plans, that those plans are hierarchically arranged, and that background knowledge and the environment interact in the creation and execution of plans for the guidance of action.

From the above, it is obvious that the Learner Goals/Objectives are an important parameter when performing personalization because they express what Learner considers as important to learn and more specifically what (s)he wants to be able to do after taking a learning experience. A learning experience that is built to satisfy Learner Goals can significantly reduce learning time while in parallel increase the efficiency of learning. Learner Goals should be taken into account both in the organization of a learning experience and the selection of its underlying content (learning objects).

Goals are generally represented as hierarchies or graphs and in domains as the project management domain, the workflows that are defined for the accomplishment of goals by are specific for a user role, independently from the individual characteristics of the person that performs each time the job. However, in learning, different workflows or paths could be defined for the accomplishment of the same learning goals and this depends on the learning style of the Learners, as well as other parameters, as his/her educational level and previous knowledge. In other words, in learning, the characteristics of each individual taking the “Learner” role are those that are influencing the definition of appropriate learning paths. This is taken into account in the present framework, where the definition of different paths for the goals’ achievement depending on the above

parameters is done through the concept of learning designs. In this framework learning designs define hierarchies of activities that are connected with specific learning goals.

Learner Goals/Objectives are usually expressed with simple text descriptions that do not represent a formal way for defining them. Consequently, this approach presents a technical barrier because textual descriptions are not machine-readable and can not be exploited by personalization systems. The framework presented in this thesis addresses this issue by providing a formal way for expressing Learning Objectives exploiting Bloom's Taxonomy of educational objectives [Bloom and Krathwohl, 1965]. Bloom's taxonomy is comprised of six levels, namely: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each level as shown in Table 2.3 has a corresponding set of descriptive verbs that can be used to form Learning Objectives. Using the Bloom's taxonomy we define Learning Objectives as pairs consisting of a verb taken from the Bloom's taxonomy and a topic referencing a concept or individual of a domain ontology.

Table 2.3 Bloom's Taxonomy descriptive verbs [Bloom and Krathwohl, 1965]

Cognitive Category	Learning Objectives Verbs
Knowledge: Recall data or information.	define, describe, identify, know, label, list, match, name, outline, recall, recognize, reproduce, select, state
Comprehension: Understand the meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.	comprehend, convert, defend, distinguish, estimate, explain, extend, generalize, give example, infer, interpret, paraphrase, predict, rewrite, summarize, translate
Application: Use a concept in a new situation or unprompted use of an abstraction. Applies what was learned in the class-room into novel situations in the work place.	apply, change, compute, construct, demonstrate, discover, manipulate, modify, operate, predict, prepare, produce, relate, show, solve, use
Analysis: Separates material or concepts into component parts so that its organizational structure may be understood. Distinguishes between facts and inferences.	analyze, break down, compare, contrast, diagram, deconstruct, differentiate, discriminate, distinguish, identify, illustrate, infer, outline, relate, select, separate
Synthesis: Builds a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new	categorize, combine, compile, compose, create, devise, design, explain, generate, modify, organize, plan, rearrange, reconstruct, relate, reorganize, revise, rewrite, summarize, tell, write

meaning or structure.

Evaluation: Make judgments about the value of ideas or materials. appraise, compare, conclude, contrast, criticize, critique, defend, describe, discriminate, evaluate, explain, interprets, justify, relate, summarize, support

From the following diagram that shows the relationship between the Kolb's Experiential Learning Cycle and Bloom's taxonomy we can extract the types of learning objectives (using Bloom's educational verbs) that are mostly appropriate to support the different learning styles defined by Kolb and the corresponding learning styles defined by Honey and Mumford. For example, to support an Activist (Concrete Experience) we should provide him/her mostly with activities and corresponding learning content with learning objectives related with Evaluation, Synthesis and Analysis.

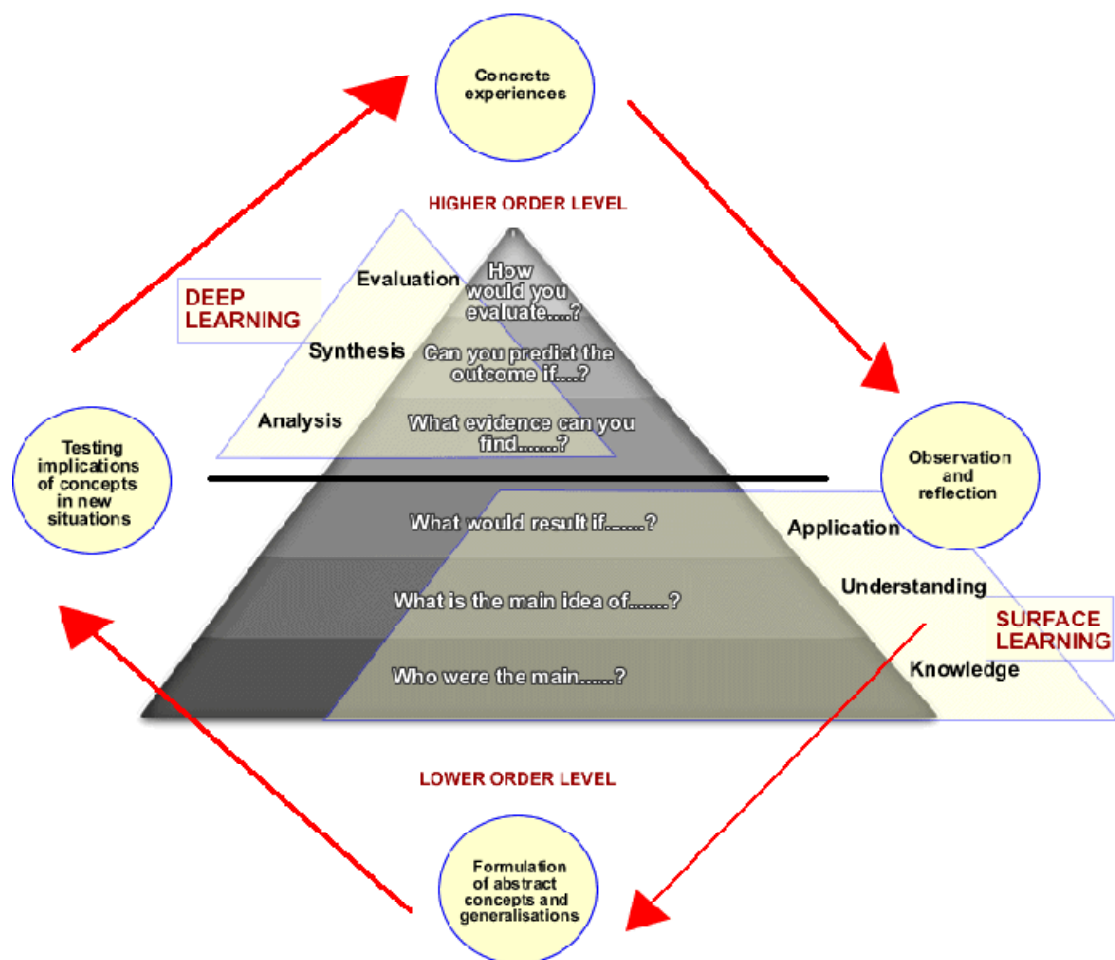


Figure 2.10 Relationship between Kolb's Experiential Learning Cycle and Bloom's taxonomy (retrieved from "The Business Case Study: A Suitable Candidate For Blended Learning?", <http://www.cluteinstitute-onlinejournals.com/PDFs/200629.pdf>)

Identifying or determining the Learner's goals and analyzing them into lower level learning goals is a very challenging task that is very difficult to be performed by the

Learner himself/herself. Usually, this requires the intervention of the instructor who will be able to determine the Learner's goals by applying appropriate methods and analyzing them into lower level learning goals to form the learning process. There are several methods that are used for the identification of the Learner's goals [Carnegie Mellon, 2009]. Our framework does not impose a specific way or method for the determination/identification of the learning goals. It is assumed that this is a matter of the user interface or it can also be done through the instructor's intervention.

2.3.1.3. Previous Knowledge

Wisniewski and Medin [Ram and Leake, 1995, chap. 6] show that prior knowledge and intuitive theories can also influence learning [see also Murphy and Medin, 1985]. They argue that tightly coupled interactions exist between knowledge and experience during learning. To the extent that learning is incremental, candidate hypothesis and theories learned earlier can influence later learning. Moreover, taking into account the previous knowledge (background) of Learners can significantly reduce learning time, since learning activities that are intended to fulfill learning goals that have been already fulfilled at a satisfactory (for the Learner) level in the past could be excluded from the learning experience.

Previous knowledge and skills are connected with learning goals/objectives. Previous knowledge can be considered as the level of satisfaction of specific learning goals/objectives.

There are several different methods to assess pre-existing knowledge and skills in students. Some are direct measures, such as tests, concept maps, portfolios, auditions, etc, and others are more indirect, such as self-reports, inventory of prior courses and experiences, etc. Below are links to some methods that instructors at Carnegie Mellon and elsewhere have employed³:

- **Concept Inventories:** Concept inventories are multiple choice or short answer tests that target fundamental concepts within a domain. These tests are designed to uncover systematic misconceptions.
- **Concept maps:** Concept map activities can reveal the underlying structure or organization of Learners' knowledge of a concept or constellation of concepts. These are very helpful when the kinds of causal theories and relations among ideas are critical to them understanding the course materials.
- **Self-Assessment Probes:** Self-assessment probes are indirect methods of assessment that ask Learners to reflect and comment on their level of knowledge and skill across a range of items. These items can include knowledge and skills

³ <http://www.cmu.edu/teaching/design/teach/priorknowledge.html>

that are prerequisites for the course as well as items that will be addressed in the course.

2.3.1.4. Educational Level and Difficulty

It is important for a learning experience to be aligned with the educational level of the target Learner regarding a domain and his/her preferred difficulty in order to be able to participate in corresponding learning activities, consume associated learning resources and transform them into knowledge. Educational level and difficulty should be taken into account both in the organization of a learning experience and its associated learning material. Thus, learning objects should also contain this info in their descriptions in order to be able to be selected during the personalization procedure.

2.3.1.5. Technical Preferences

Technical preferences can include Learner's devices, internet connection etc. These preferences do not influence the organization of the learning plan but are taking into account in the selection of appropriate learning objects.

2.3.1.6. Other Preferences

Preferences regarding language, learning provider (the author or organization making available the learning objects), learning planner (the person that organizes the learning process in terms of learning designs), etc. Preferences regarding language and learning provider affect the selection of learning objects, while the preference regarding learning planner affects the selection of the learning plan.

2.3.2. Adaptive eLearning Systems

Within the field of technology enhanced learning, adaptive educational systems offer an advanced form of learning environment that attempts to meet the need of different students. Such systems build a model of the student's knowledge, goals and preferences, and use the generated model to dynamically adapt the learning environment for each student in a manner that best supports learning [Brusilovsky, 2001]. However, major research questions exist such as: how are the relevant learning characteristics identified, how does modeling of the learner take place and in what way should the learning environment change for users with different learning characteristics [Papanikolaou and Grigoriadou, 2004]? Strategies that have been used to adapt to these learner characteristics include annotating links, hiding links, changing the sequence of material and hiding or tailoring the content [Brusilovsky, 2001].

To describe **adaptive eLearning systems**, one may distinguish between the following major concepts:

- The **domain model**: a model of the learning content of the system. The domain model defines the conceptual design of the system and essentially specifies what can be adapted. It is based on an appropriate modeling of learning objects (their structure and semantic information).
- The **learner model**: a model of the learner's knowledge and preferences. The definition of the learner model is based on the domain model so that the current state of the learner could be described. This current state reflects the learner's knowledge with respect to the concepts of the domain model. User's knowledge is usually given in terms of learning objectives/competencies that have been accomplished [Bloom and Krathwohl, 1965]. The desired learning objectives/competencies may also be recorded to facilitate the delivery of adequate learning material to the user. These learning objectives/competencies are linked to domain concepts. User preferences may include learning styles, preferred language, preferred presentation styles etc. The term learner profile is usually used to refer to the learner related information that is exploited for adaptation of the content and the presentation mechanisms so that individualized services could be offered.
- The **context model**: a model of the current setting of the system with respect to a specific user. This model is used to adapt the system's behavior depending on various parameters such as the devices used by a user or the place that the user is currently located.
- The **instruction model**: a model for specifying a pedagogical approach (or a set of approaches) used for the navigation and the presentation of the learning content to meet individual needs and preferences.
- The **adaptation model**: a model of the adaptation semantics. It defines the status of adapted objects and their parts based on the related parameters and concepts of the user model and the context model. It may also specify adaptation techniques to be used such as adaptive learning activity selection, adaptive recommendation of learning material or adaptive learning service provision.

Several adaptive educational systems that adapt to different learning characteristics have been developed [Kelly and Tangney, 2006]. CS383 [Carver et al., 1999] modifies the presentation of content for each student using the Felder & Silverman learning style model. Before using the system, learners submit a questionnaire. Subsequently this information is used to adaptively present media elements in a sorted list ranked from the most to least conducive based on their effectiveness to each student's learning style. AES-CS [Triantafillou et al., 2003] uses the field-dependence/field-independence cognitive learning theory as the basis for adaptively providing learner control, contextual

organizers and lesson structure support. INSPIRE [Papanikolaou et al., 2003] also uses a questionnaire to classify students as activists, pragmatists, reflectors or theorists according to Honey & Mumford's theory [Honey and Mumford, 1986]. This system adapts the order of presentation of different types of resources according to the learning style of the student.

Another category consists of those systems that use machine learning techniques to develop and refine a model of learning characteristics [Specht and Oppermann, 1998; Gilbert and Han, 1999; Stern and Woolf, 2000]. These systems build a model of learning characteristics using feedback from the student using questionnaires, navigation paths, answers to questions, directly requesting feedback, allowing the user to update their own student model and to make specific adaptations such as sorting links or viewing stretch text. Typically the systems contain a variety of instructional types such as explanations, examples or fragments of different media types representing the same content. Based on information in the learner model, the tutoring system chooses the most suitable instructional type from the range available. For example, ACE [Specht and Oppermann, 1998] adapts the sequence of material based on the success of the currently used teaching strategy. The success of a strategy is mainly determined by the learner's performance in the tests where repeated occurrences of high performance raise the preference value of the strategy. ARTHUR [Gilbert and Han, 1999] is another system that illustrates how to dynamically adapt instructional style to learner's performance in tests. It uses multiple versions of the same resource created using different instructional styles such as: visual-interactive, auditory-text, auditory-lecture, and text style. To determine the instructional style an inference engine, based on case-based reasoning, compares the student's performance in tests to that of other students and matches students with instructors who can work successfully with that type of student. In contrast, iMANIC [Stern and Woolf, 2000] adapts the presentation of content based on the learner's selection of different types of resources. When presenting the concepts, the student interaction data is analyzed using the Naïve Bayes algorithm to determine which resources are wanted and should be presented first. Developing systems that use intelligent techniques for diagnosing learning characteristics offers a promising research direction, however such systems in addition to validating the effectiveness of the adaptation strategies, also need to identify appropriate behavioral indicators and validate the accuracy of the inference techniques that analyze the interaction data.

Most Adaptive eLearning Systems will generally have a separate learner and content model with the narrative model embedded in the content or adaptive engine itself. The approach used in APeLS [Clarke, 2003] is described as a multi-model approach with the adaptive engine being fed by these three models [Dagger et al., 2003]. The three main models in APeLS are the learner, content, and narrative models. The learner model contains modelled assumptions that represent the characteristics of the student that are

important to the system [Conlon et al., 2002]. These could be the learner's goals, learning style etc. The content model represents the learning resources within the system and the narrative (pedagogical) model represents the ways in which the content can be sequenced for the learner [Conlon et al., 2003].

AHA! [Stash and De Bra, 2003] contains one model less than APeLS, the two models being the user (e.g. the Learner) and domain/adaptation models. The user model here is analogous to the learner model of APeLS maintaining relevant information about the learner using the system. The domain/adaptation model contains the concepts taught, the relationship between these concepts along with the embedded adaptive logic. The domain/adaptation model is similar to the narrative model of APeLS, however its big disadvantage is the intertwining of the domain, content and adaptive techniques.

Similar to APeLS and AHA, 3DE [Sarrikoski et al., 2000] maintains a model of the learner, or more precisely a profile of the learner. This profile maintains data pertaining to the learner's goals, competence and learning style. Unlike AHA! this profile is not updated as the learner moves through the course, but it is only updated at the start of the session when the student selects the relevant learning goals and/or completes the learning style questionnaire to reveal his/her dominant learning style. The content elements are organized in a hierarchy of atom, content unit, composite unit and courses. The content units of the 3DE system are analogous to the Learning Objects of APeLS. The custom course compiler builds a customized course from the micromodule library taking into account the learners goals and learning style along with the prerequisites required.

Major shortcomings of existing adaptive educational systems are:

Pedagogy (the how-to-teach) is not taken into account. Even if it is taken into account, important parameters as learning objectives, educational level, previous knowledge, etc. are not always taken into account

Although adaptivity in eLearning has become one of the key aspects in Adaptive eLearning Systems, such adaptivity has tended to focus on adaptive content retrieval and (simple) content sequencing based on domain models, or more recently ontologies [De Bra et al., 2003]. From an educational (learning) perspective, this adaptive content retrieval typically supports lower cognitive aspects of learning (recall & understanding) [Bloom and Krathwohl, 1965]. To provide support for higher cognitive skills in areas, such as analysis, synthesis and evaluation, the adaptivity needs to be intimately integrated with sound pedagogic approaches and models [Johannesson, 1997; Brusilovsky, Eklund and Schwarz, 1998]. Important parameters that affect learning such as learning objectives, educational level, previous knowledge etc. should be taken into account in the adaptation process. However, this is not always the case in Adaptive eLearning Systems.

The instructional model is bound with the domain model (content) or the adaptation model (adaptation engine)

Although there tends to be separation of the learner model and the content model in Adaptive eLearning Systems, the narrative or pedagogical model is usually embedded in the content or the engine [Brady, Conlan, and Wade, 2004]. In these cases, adding new or different pedagogical models to the content model is more difficult and involves a re-authoring of the content model. This results in learning content that is difficult to reuse or an engine that is domain specific. One means of enhancing the educational impact of eLearning courses, while still optimizing the return on investment, is to facilitate the personalization and repurposing of learning objects across multiple related courses [Conlan et al., 2002].

Some Adaptive eLearning Systems are dependent on a specific learning style approach that is usually bound/incorporated in the adaptation strategy (algorithm) or the domain model

Some Adaptive eLearning Systems are dependent on a specific learning style approach that is usually bound/incorporated in the adaptation strategy (algorithm) or the domain model. That means that the adaptation model or the domain (content) model are dependent on this specific learning style approach and can not be reused in other learning style approaches. Usually, learning objects metadata include appropriateness for specific learning styles according to a specific learning style approach. For example, in 3DE Project [Sarrikoski et al., 2000] micromodules (learning objects) descriptions contain this info in terms of percentages following the Honey & Mumford learning styles approach (Activist=75%, Reflector=25%, Theorist=25%, Pragmatist=50%). Beyond the obvious problem that arises from the difficulty that an annotator has to overcome in order to associate such kind of percentages in learning objects descriptions there is also a more important problem related with the reusability of those learning objects to support other learning styles approaches (there are almost 101 in bibliography).

Lack of generality, i.e. capability of the system to support any teaching domain

Another problem faced by current AES is generality, i.e. the capability of the system to support any teaching domain [Surjono, 2007]. Most current AES have fixed knowledge domains which are not easily expandable or adaptable to other subject matter [Carver et al., 1999; Wu, De Kort, and De Bra, 2001]. It is difficult to update teaching materials in AES or to author a new one with new subject matter [Carro, 2002]. An AES should be reusable in different domains of knowledge and can be built and maintained easily [Melis et al., 2001].

Complexity, cost and effort required to develop adaptive eLearning experiences is very high

A usual problem in Adaptive eLearning Systems is that the complexity, cost and effort required to develop adaptive eLearning experiences is very high (or intelligent tutoring systems) [De Bra et al., 2000; Dagger, Conlan and Wade, 2003a; Conlan and Wade, 2004]. Because of this fact, applying personalization through adaptive learning experiences is not scalable within learning institutions, typically schools, higher education and further education.

2.4. The most related work of the related...

Efforts trying to integrate or use in cooperation eLearning standards and A/V standards include Video Asset Description (VAD) Project [Bush et al., 2004], Multimedia Learning Object Server [Amato et al., 2004] and Virtual Entrepreneurship Lab (VEL) (Klamma, Jarke, and Wulf, 2002). Most of these approaches [Amato et al., 2004; Klamma, Jarke, and Wulf, 2002] use mappings between standards (e.g. MPEG7 and LOM) or propose adding MPEG7 elements to SCORM elements [Bush et al., 2004]. However, as it has been already explained, using mappings between standards or mixing them creating application profiles is not an efficient solution to solve the interoperability problem between digital libraries and eLearning applications. The framework proposed in this thesis is more generic and has not been developed as yet another local solution. Thus, it does not depend on the strict use of MPEG7 and LOM and can also be used to support interoperability of other types of applications (not only eLearning) with digital libraries. The interoperability architecture proposed here conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification. Web service implementations based on IMS DRI include the EduSource Canadian Network of Learning Objects Repositories (EduSource Canada), the Learning Objects Network (LON) and the Campus Alberta Repository of Educational Materials (CAREO). Our approach differs in that it provides an interoperable framework of educational and application specific metadata so that eLearning applications can easily use and reuse digital library objects in multiple contexts.

The framework presented in this thesis clearly separates pedagogy from content in order to exploit reusability of abstract training scenarios in various learning situations. In [Capuano et al., 2005] a similar approach is followed to represent pedagogy in order to support run-time resource binding. Our approach differs in that it takes into account the learning style, the educational level and learning goals of the Learners, supporting the representation of different learning paths (Training Methods) for training in a specific subject. In [Meisel et al., 2003], although the need for supporting different training methods for the same subject is recognized, these methods are not connected as in our approach with the learning styles and educational levels of the Learners. Moreover, description of appropriate learning objects characteristics beyond semantics is not supported. An alternative approach is presented in [Karampiperis and Sampson, 2004] regarding automatic course sequencing. In that work learning paths are not constructed based on pedagogical models, but are extracted from a directed acyclic graph that is the

result of merging the knowledge space (domain model) and the media space (learning objects and their relation) using minimum learning time as an optimization criteria. However, since this approach is highly based on the domain model that does not necessarily imply an instructional model, and also on the relations of learning objects and their aggregation level, there is a risk that the result of the sequencing process may be not always “pedagogically-right” adapted to the Learners’ various learning styles. The same authors presented more recently [Karampiperis and Sampson, 2006] an approach based on competencies on top of a model supporting learning objectives built using domain ontologies. Again, the same shortcomings can be identified related to the lack of reference to learning styles and other pedagogical parameters explicitly used in our case. Azevedo et al. [2006] use IMS-LD based templates and domain ontologies to contextualize and reuse Learning Objects in different learning experiences but do not explicitly focus on personalization and do not support alternative packaging of courseware as the framework of this thesis does.

The closest work to the approach presented in this thesis regarding personalization is the multi-model, metadata driven approach to adaptive hypermedia services for personalized eLearning [Conlan et al., 2002]. This approach has a clear separation of content, learner and narrative models, and a generic adaptive engine that employs a multi-tiered AI model to achieve adaptation according to the learner’s requirements. The authors propose extension of LOM standard in order to include an adaptivity element for the adaptive selection of learning objects. Possible values of the adaptivity are: `learningstyle`, `competencies.taught`, `competencies.required`. This approach has two shortcomings: 1) Extending LOM leads to interoperability problems, 2) Associating a learning resource with a specific learning style prohibits its exploitation in other learning styles or even in other learning styles approaches. Moreover, in this approach the courseware author should define sets of candidate learning resources at design time. This significantly reduces the scope of candidate learning objects that can be selected at run-time and bound to the training scenario to satisfy the learner’s needs. The advantage of the approach presented in this thesis is that it does not modify LOM in order to achieve adaptive selection of learning objects, but it appropriately uses existing LOM elements to encapsulate the needed for the adaptation process information. Moreover, learning objects, as defined in this framework, are not associated with a specific learning style, but a number of metadata elements (e.g. `learningResourceType`, `semanticDensity`, `interactivityType`, `interactivityLevel`) are used at run-time to check their appropriateness depending on the requirements expressed in each activity of the abstract training scenario (learning design). Finally, learning objects or sets of them are not bound to the training scenario at design-time, but are selected and retrieved from repositories at run-time according to the needs of the Learner and the special requirements given at the training scenario’s activities.

2.5. Summary

In this chapter some of the most important standards and specifications in eLearning and digital libraries domain have been presented and their role in this thesis has been explained. Moreover, the parameters that affect learning according to the bibliography have been introduced. These are taken into account in the framework presented in this thesis in order to create higher level objects that are finally delivered to the Learners by eLearning applications as learning experiences. Systems that are able to generate personalized learning experiences based on Learner's characteristics are called Adaptive eLearning Systems. However, these systems present several shortcomings. These shortcomings have been analyzed and the advantage of the approach presented in this thesis has been discussed. Finally, the most related works were presented and they have been compared with the framework developed in this thesis.

The concepts, standards and technologies introduced in this chapter have been exploited in this thesis in order to provide a complete framework and an architecture for the gradual development and generation of personalized learning experiences from audiovisual digital library objects making able the exploitation of audiovisual objects from eLearning applications, that will be presented in Chapter 3 and further described in the rest of this document.

Chapter 3. AN ARCHITECTURE FOR SUPPORTING INTEROPERABILITY OF DIGITAL LIBRARIES WITH ELEARNING APPLICATIONS (ASIDE)

3.1. Introduction

In this chapter, a generic interoperability framework and an architecture is presented for supporting interoperability between digital libraries and (eLearning) applications. This framework facilitates the integration of various technical solutions through agreement on services definitions, behaviours, data models and protocols. The framework has not been developed as yet another local solution that focuses on eLearning applications but having the broader problem of interoperability between digital libraries and applications in mind. Thus, it could be also applied to other types of applications built on top of digital libraries, since it supports multiple contexts and views of the digital objects of a library, although in this thesis we focus on eLearning applications. To achieve that, the framework exploits the well-known digital library standard METS and has been implemented in a service-oriented architecture according to the recommendation of the IMS DRI specification. Integral part of this framework is the dynamic creation of pedagogy-driven personalized learning experiences exploiting the underlying audiovisual content that allows for needs of different Learners to be met.

3.2. Supporting multiple (educational) context views of digital objects using METS

In 0 we mentioned that the “how” a digital object has been described through metadata (context) determines the application by which it can be discovered and utilized. Or inversely, the intended use/application affects how a digital object should be described. So, a digital object can be described in many ways and delivered to many applications as illustrated at the upper part of Figure 3.1. However, performing just a transformation between the source and target metadata schemes is not always a panacea. As shown in 0, standards do not always completely overlap and in the non-overlapping areas the interoperability problem cannot be simply solved using mappings. For example, SCORM contains an educational part that cannot be mapped to MPEG7 elements. Very often we want A/V digital objects that reside in a digital library and are described with MPEG7 to be used in eLearning applications. However, the MPEG7 descriptions do not say anything about the educational use (e.g. learning objectives) of the digital objects. On the other hand, MPEG7 offers a comprehensive set of audiovisual Description Tools, which can not be represented in SCORM.

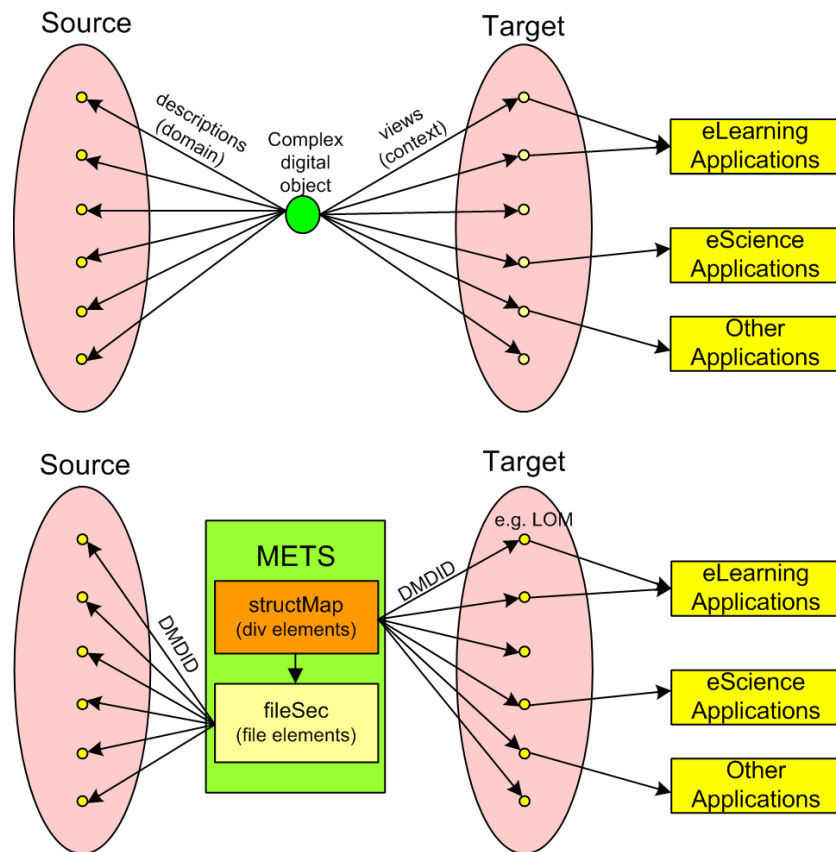


Figure 3.1 A digital object can be described in many ways and used in many applications. The “how” a digital object has been described through its metadata (context) determines the application from which it can be retrieved and used. Or inversely, the intended use/application affects how a digital object is described. Using METS multiple-contexts views of digital objects can be supported.

Moreover, a digital object can have many educational uses and these determine whether a digital object becomes a learning object or not. Depending on the target learning use a digital object or parts of it may have to be combined with other digital objects or parts of them to comprise a learning object (Figure 3.2). However, we cannot predict all possible educational uses of a digital object. Although we cannot predict all of them we should somehow associate educational characteristics to digital objects in order to be able for them to be exploited by eLearning applications.

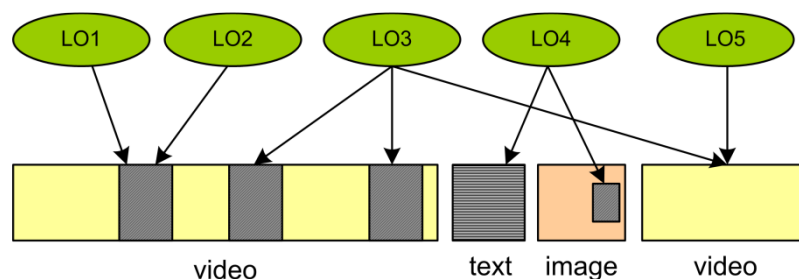


Figure 3.2 Depending on the target learning use, a digital object or parts of it may have to be combined with other digital objects or parts of them to comprise a learning object

In order to overcome these above shortcomings it is of great importance to provide the ability to re-purpose or enable others to **locate** and **re-purpose** digital objects in

different (educational) contexts, while in parallel retaining their audiovisual characteristics. Repurposing digital objects for different educational contexts requires a flexible data model for the uniform treatment of digital objects. This model should support multiple contextual views (through descriptive metadata) of digital objects, in order to be able for these objects to be discovered, used and reused by various applications. These views of a digital object should not be attached to the initial object, but should reside at an upper level (context level) referencing the original object. In parallel, access to the original object administrative (e.g. audiovisual) characteristics should be possible in order to be able to use this object through different media (e.g. devices). Moreover, the structural model (structural metadata) for the representation of the structure of the digital object should be neutral and independent from the context. In Chapter 1 we saw that neither MPEG7 nor SCORM could be used as they are to satisfy these critical needs because of the shortcomings presented above. In order to overcome these shortcomings and fill in the gaps between SCORM and MPEG7 we have to use a higher level metadata model.

A flexible model that satisfies the above needs is METS [METS, 2005]. As already mentioned, METS is the first widely-accepted standard designed specifically for digital library metadata. METS is a flexible, but tightly structured, container for all metadata necessary to describe, navigate and maintain a digital object: descriptive, structural and administrative. Each type of metadata is described in a separate section, which is linked to its counterparts by internal identifiers. These metadata (any preferred scheme) may be physically stored within the METS file, or in external files referenced from within the METS document.

Using METS we can create different views of a digital object pointing to both source metadata description and target metadata description (context) in different levels [Arapi, Moumoutzis, and Christodoulakis, 2006]. The methodology is illustrated at the lower part of Figure 3.1. Using the DMDID attribute of the <div> elements of structMap section where the structure of the digital object is described we can point to an appropriate metadata description according to a specific metadata scheme creating a context (view) of this object or parts of it. For example, we can use LOM metadata [IEEE LOM, 2002] to describe the educational characteristics of the object (or parts of it), so that being able to be searched and retrieved by eLearning applications (educational context). In parallel, using the DMDID attribute of the <file> elements of fileSec section, where all files comprising a digital object are listed, we can point to the original audiovisual descriptions that also include useful technical and other administrative information for the object (e.g. using MPEG7). This way, different views of the same audiovisual object or parts of it can be created on top of it without modifying the original object.

Let's consider the case illustrated in Figure 3.3, where the same video segment is used for two different pedagogical purposes. Imagine for example that this segment shows two fishermen fishing on the Missouri River. One possible educational use of this segment could be to demonstrate a fishing technique, while another use of this segment could be to introduce conditionals in the English language. These two different uses of the segment comprise two different views on it. Thus, they are represented with two separate METS files having the same structure, but different LOM descriptions describing the two different pedagogical uses of this segment.

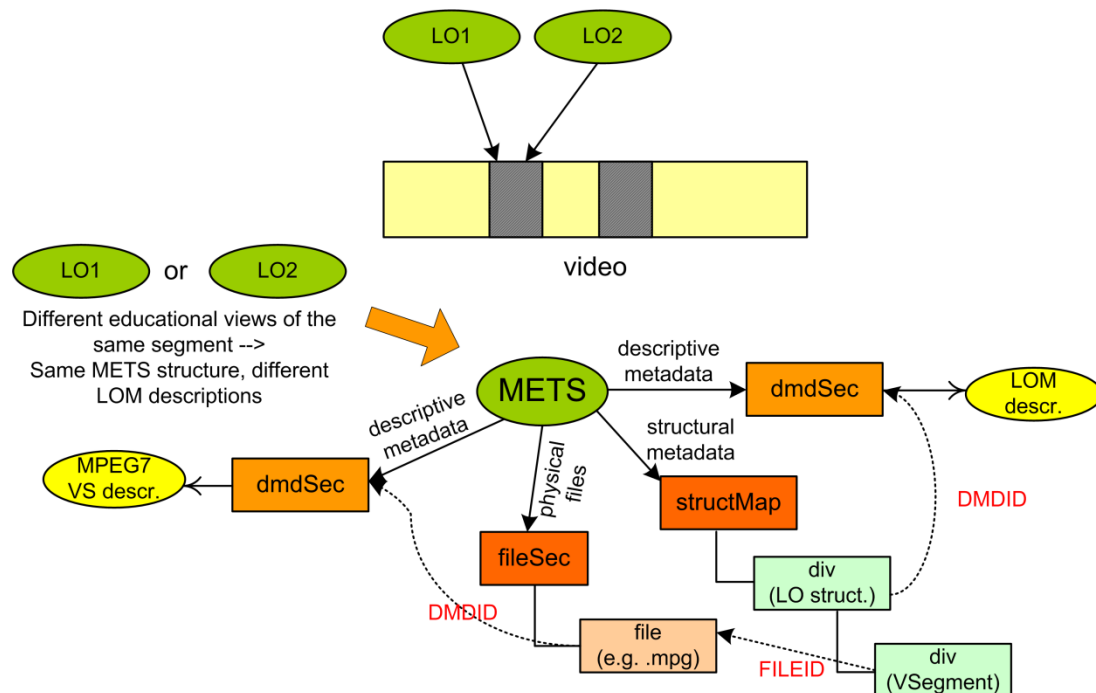


Figure 3.3 LO1 and LO2 are different educational views of the same video segment. Thus they are represented with two separate METS files having the same structure, but different LOM descriptions describing the two different pedagogical uses of this segment

Figure 3.4 shows a case where two segments of a video object should be combined with another digital object (video) in order to comprise a learning object able to fulfill the target learning use.

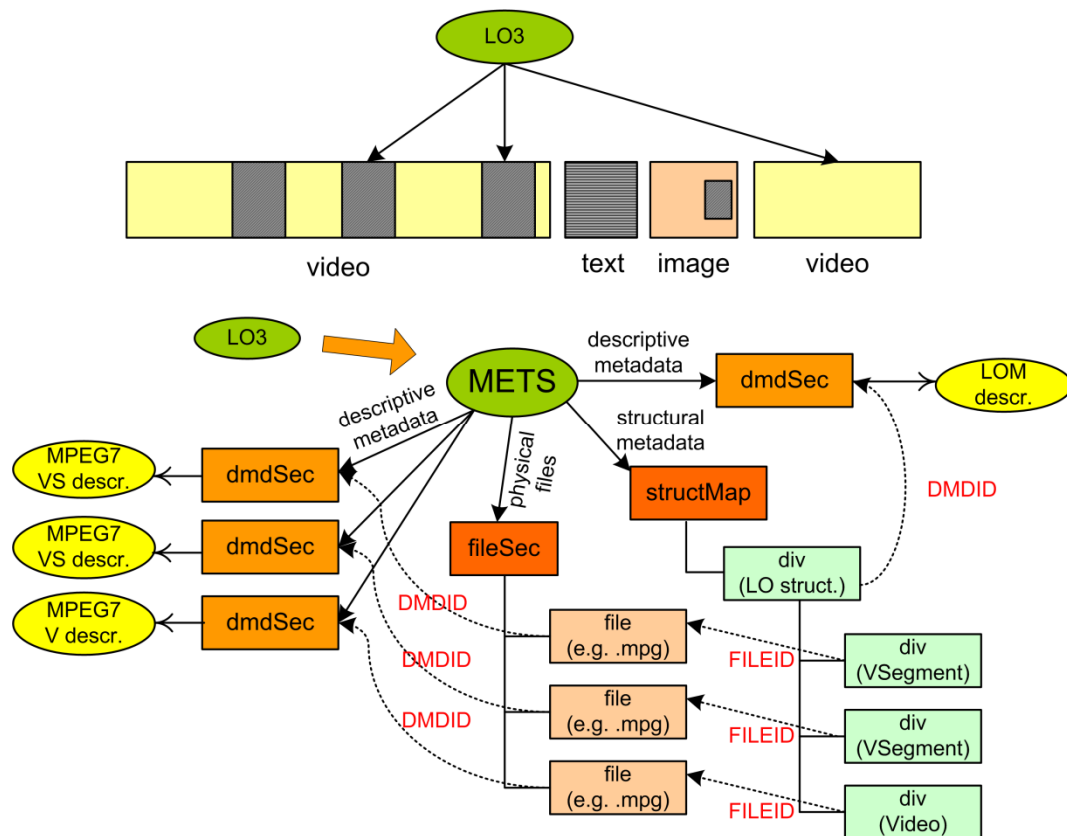


Figure 3.4 Two segments of a video object are combined with another digital object (video) in order to comprise a learning object able to fulfill the target learning use

Supporting multiple (educational) context views of digital objects using appropriate data models is only one aspect of the problem. The other aspect has to do with supporting the repurposing of digital objects to higher level learning objects and finally learning experiences through appropriate architectures.

3.3. Towards generic repurposing infrastructures

In a traditional scenario, digital objects residing in a database of homogeneous content are repurposed through an application specific tool to digital objects of the same type. For example, a LCMS playing the role of the repurposing tool discovers learning assets residing in a learning object repository and described with learning object metadata and forms a learning unit to fit to the target educational context. The outcome of this process is a learning object that is stored again in a learning object repository and is available to be consumed by a LMS. As already mentioned in 0, this scenario is very restrictive since it does not allow the exploitation of various types of digital objects that may comprise useful learning resources in the creation of learning objects.

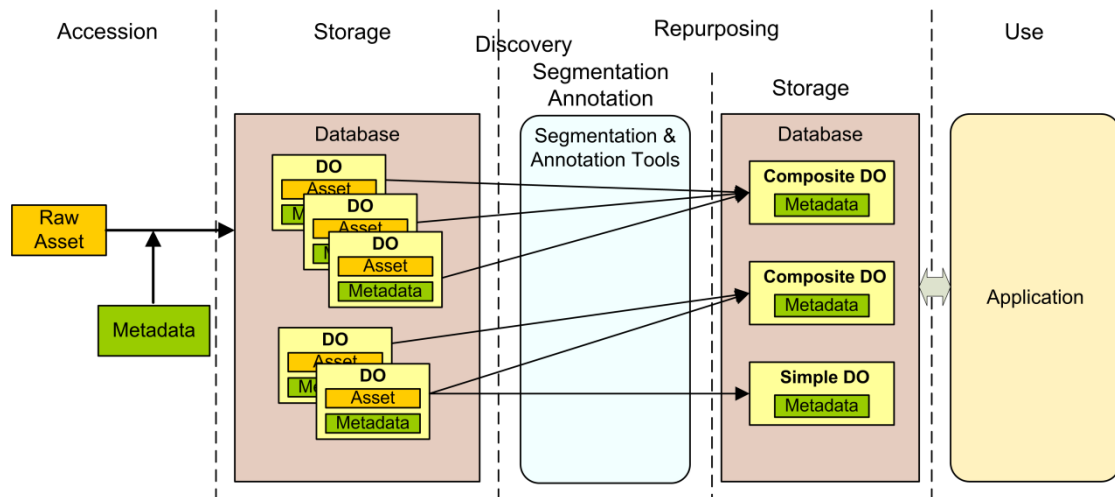


Figure 3.5 The typical process of repurposing of a digital object. Initially raw assets have been enriched with metadata (initial context) and stored in a database (homogeneous collection of digital objects described using a specific metadata model or domain ontology). Repurposing includes the following phases: a) Discovery, where an appropriate digital object (or multiple digital objects) is/are found from a database, b) Segmentation and Annotation of digital objects in order to create a new version (simple or composite DO) that corresponds to the target context, and c) Storage of the newly created DO in the same database or in a similar one (following the same metadata model).

In the envisioned scenario, appropriate digital objects can be discovered from multiple heterogeneous collections described with various metadata models, and adapted through a common adaptation service to fit to the target (educational) use. Since adaptation/repurposing process is the same and independent from the target application, this common functionality could be exploited by various object creation environments (e.g. LCMS) if it is given in the form of services or plugins. The only difference is the metadata model/domain ontology that is used to describe the newly created object, depending on the target use. For example, LOM metadata could be used to describe the new object in an educational context to be available to LMS. Depending on the target context, appropriate metadata models/domain ontologies can be loaded to describe the final object. In this scenario, an author could use this repurposing service through a LCMS in order to discover and repurpose various types of digital objects to create learning objects. Similarly, an author from a cultural environment could use the same repurposing service in order to discover and repurpose various types of digital objects to create cultural objects. Finally, the newly created object can be stored in an appropriate database to be consumed by relevant applications. For example, if the result of the repurposing process is a learning object it will be stored in a learning repository hosting objects of the same type.

The tools supporting this generic scenario should be able to:

1. Discover one or more digital objects from multiple digital libraries,

2. Repurpose this object. This may include segmentation of this object and/or combination with other objects and description with appropriate metadata/domain ontologies depending on the current context.
3. Store the new version in an appropriate digital library/repository depending on the target application of the repurposed object.

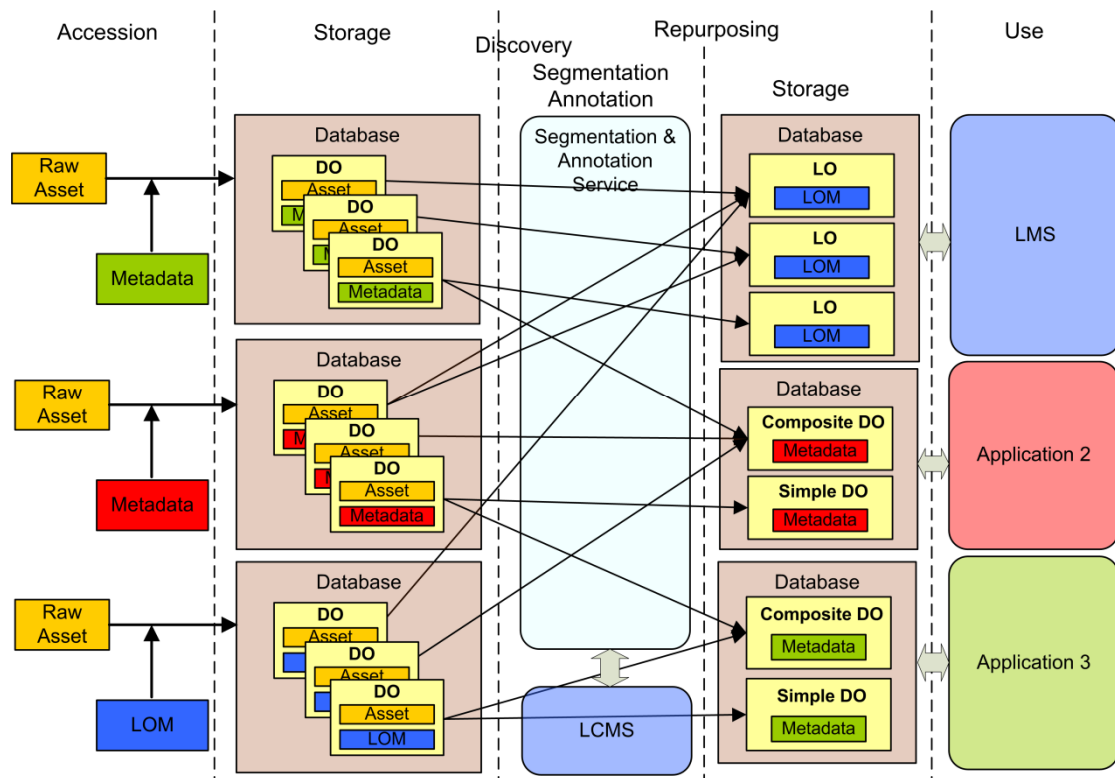


Figure 3.6 Envisioned repurposing scenario. Repurposing includes the following phases: a) Discovery, where digital objects can be found from heterogeneous collections, b) Retrieved digital objects can be repurposed through a common segmentation and annotation service which can be exploited by many editing applications (e.g. a LCMS in case of eLearning). This service provides common functionality to editing applications while in parallel makes possible the repurposing of digital objects for different uses using the appropriate each time metadata model/ontology. c) Repurposed digital objects are stored in appropriate homogeneous collections depending on their target application. These collections (e.g. digital library/repository) provide common services for the storage and management of their underlying content. Finally, the repurposed digital objects can be discovered and consumed by the corresponding end applications (e.g. a LMS).

This generic repurposing scenario requires discovery and access of various types of digital objects described differently and stored in different places. This problem is a classical digital library interoperability problem that has to do with how heterogeneous collections can be accessed in a uniform manner. This requires digital library components or services to be functionally and logically interchangeable and having a set of well-defined, publicly known interfaces. Towards this end, different services and components should be able to communicate with each other through open interfaces, and clients interacting with them in an equivalent manner. If repositories and digital objects are created this way, the overall effect can be a federation of repositories that aggregate

content with very different attributes, but that can be treated in the same manner due to their shared interface definitions [Payette et al., 1999].

To address this problem, a common set of operations should be defined in the form of services to perform basic repository management functions. For this reason this framework proposes the implementation of the most common repository functions as described in IMS Digital Repositories Interoperability (IMS DRI) Specification [IMS DRI, 2003]. The IMS DRI specification introduced in Chapter 2 provides recommendations for the interoperation of the most common repository functions enabling diverse components to communicate with one another: search/expose, submit/store, gather/expose and request/deliver. These functions should be implementable across services to enable them to present a common interface.

3.4. The ASIDE architecture

The architecture presented here addresses the identified interoperability problems in a layered architecture where eLearning (and other) applications are built on top of audiovisual digital libraries and utilize their content. The ASIDE architecture [Arapı, Moumoutzis, and Christodoulakis, 2006] illustrated in Figure 3.7 consists of layered repositories supporting the gradual creation of learning experiences starting from existing content residing at audiovisual archives and offers a generic framework for the dynamic creation of personalized learning experiences using reusable audiovisual learning objects. It is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification [IMS DRI, 2003]. The IMS DRI specification introduced in Chapter 2 provides recommendations for the interoperation of the most common repository functions enabling diverse components to communicate with one another: search/expose, submit/store, gather/expose and request/deliver. These functions should be implementable across services to enable them to present a common interface. IMS DRI splits services into three categories:

- Access services (resource utilizers): Services with which the end user interacts (e.g. LMS/LCMS, portal)
- Provision services (repositories): Services that make content available, and
- Intermediaries: Services that reside between the above two (e.g. aggregators, brokers)

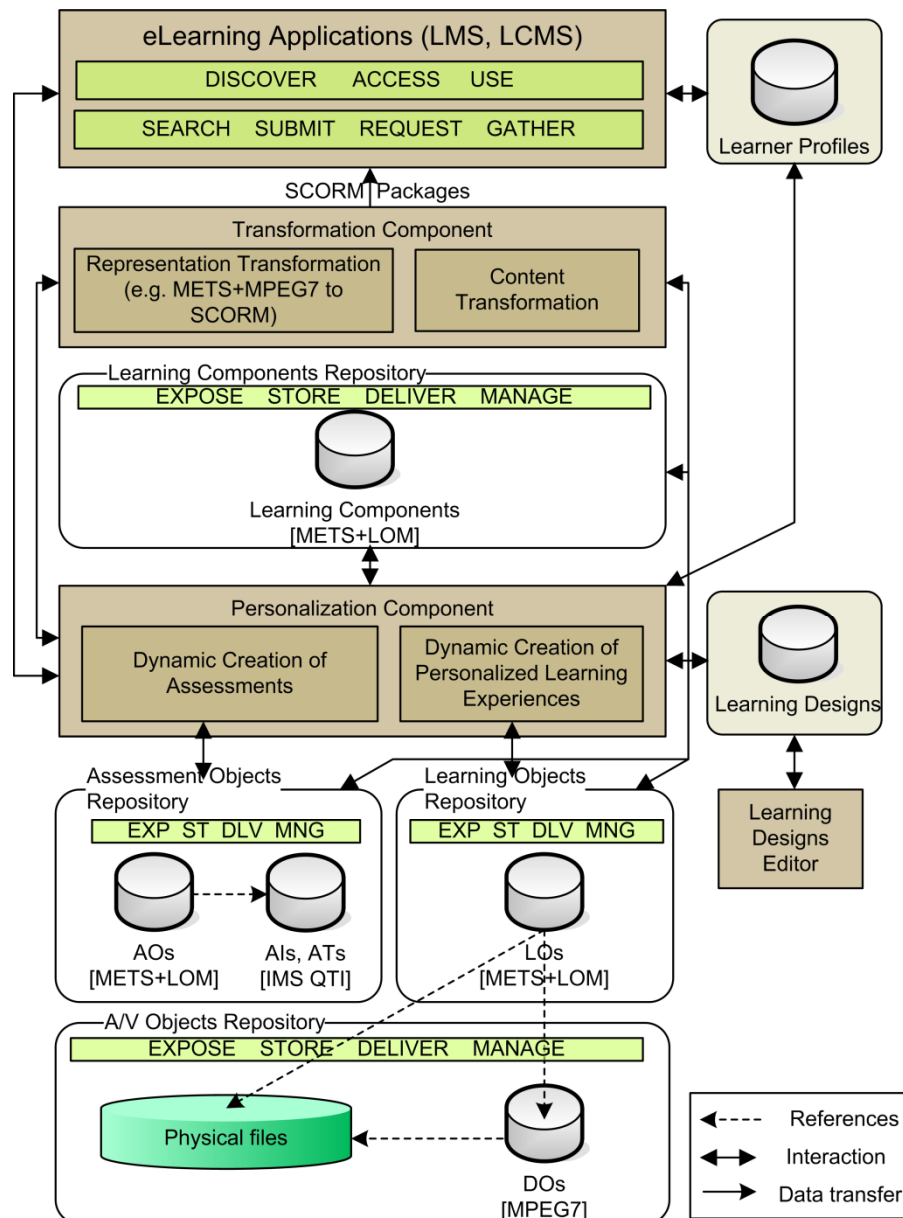


Figure 3.7 The ASIDE architecture

Figure 3.7 illustrates the architecture components, which are the following:

- Appropriate **repositories and services** for the management of various types of objects:
 - **Audiovisual Digital Objects (AVOs)** created on top of Media Objects that correspond to content assests or parts of them annotated and indexed with administrative and semantic metadata,
 - The **Learning Objects (LOs)** built on top of Audiovisual Digital Objects and enriched with educational metadata. A learning object is a collection of Digital Objects that are assembled to teach a single learning objective.

- **Assessment Objects (AO)** that are used to assess the satisfaction of certain learning objectives. Assessment Objects could be simple questions (Assessment Items) or complex questionnaires consisting of Assessment Items (Assessment Tests). AOs are also described with educational metadata.
 - **Learning Components (LCs)** corresponding to learning experiences utilizing the underlying Learning Objects and Assessment Objects and that can be delivered using different delivery devices. They are hierarchies of activities supported with LOs or AOs and they are described with educational metadata and possibly sequencing and navigation metadata.
- **eLearning Applications** (Software Agents in terms of IMS DRI, like Learning Content Management Systems, Learning Management Systems etc.) that discover, access and use the content of the A/V content of the digital library through appropriate services (resource utilizers). Authoring tools for the authoring of the above types of objects as well as Learning Management Systems for the delivery of learning experiences to Learners are considered as applications. Learning Management Systems in this framework include components encapsulating functionality to adapt the learning material to individual user needs and context as well as to track user's progress and update the user related information represented in Learner Profiles.
- The **Personalization Component** residing between the Learning Objects Repository level and the Learning Components Repository level and used for the **Dynamic Creation of Personalized Learning Experiences** according to specific learning needs expressed in **Learner Profiles** and using a set of abstract training scenarios (**Learning Designs**) constructed using a tool named **Learning Design Editor**. This service can be exploited both by Learners as learning experiences and by courseware authors providing them a semi-automatic method for the creation of courseware. Before transforming the resulted learning experience to a SCORM package, it is stored as a Learning Component being ready and available in an interoperable way for later requests. The Personalization Component encapsulates functionality for the **Dynamic Creation of Assessments** from Assessment Objects in order to “measure” the previous knowledge of the Learner and update his/her Learner Profile.
- The **Transformation Component**, which is responsible for the transformation of the objects' METS-based descriptions to SCORM Content Packages [SCORM, 2004]. This includes not only simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Moreover, the type of the underlying physical files is taken into

account (from MPEG7 descriptions), as well as the requirements of the delivery channel and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files) and appropriate content transformations are performed.

3.4.1. Domain modeling

ASIDE follows a hierarchical approach in the categorization of the objects it manages, and their representation is based on the framework presented earlier that exploits METS standard. There are several reasons and advantages of this approach:

- It makes possible the reusability of lower level objects from higher level objects and reduces the development cost of learning content.
- It efficiently supports the gradual development of learning resources starting from existing media that reside in external digital libraries, while in parallel it supports the delivery of this material using multiple delivery channels.
- It makes possible the exploitation and delivery of the underlying objects to different channels (devices).

The above are possible, since this approach allows for:

- Integrated description of objects at each level using several appropriate (metadata) schemes to represent the different aspects of objects.
- References to objects residing at lower levels without repeating their information at the current level. Generally, objects residing at a certain level are able to reference objects at the level underneath. Moreover, this flexible representation of objects allows for appropriate adaptation/transformation of objects at run-time in order to support cross-media delivery of learning experiences.

The following figure illustrates the relation among LCs, LOs, AOs, AVOs and Content Assets residing in corresponding repositories.

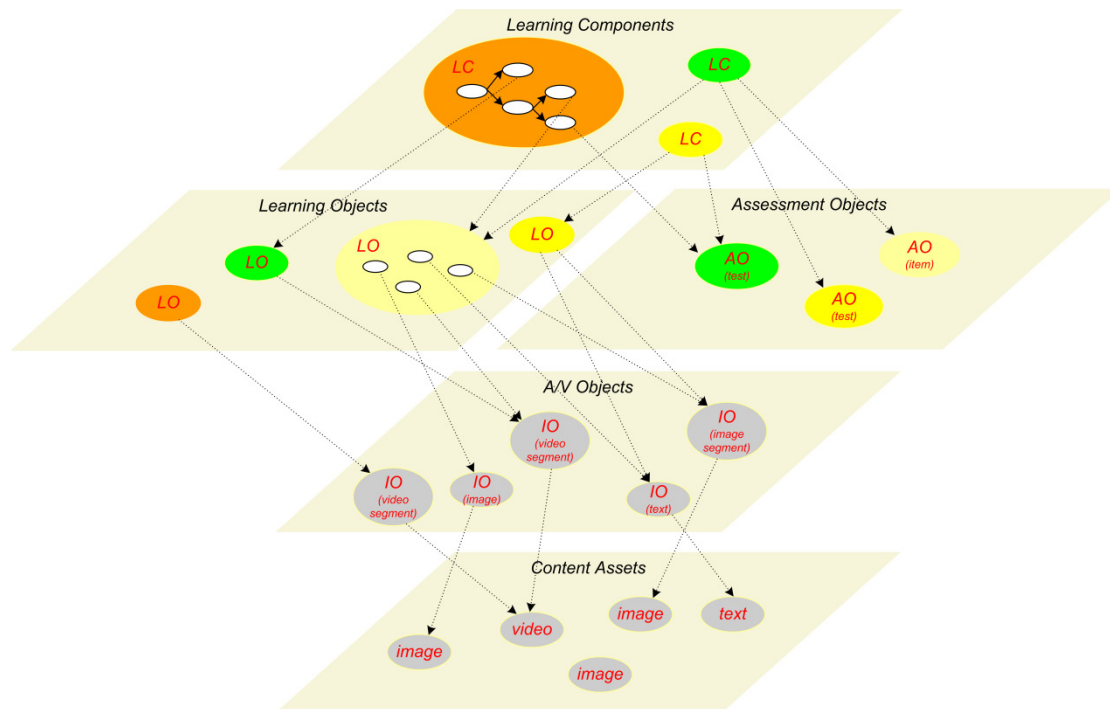


Figure 3.8 Relation among COs, LOs, AOs, DOs and Media Objects residing in corresponding repositories and the Media Server

Figure 3.9 illustrates how METS is used for the representation and description of AVOs, LOs, AOs and LCs, according to the framework presented. Specifically:

- **Audiovisual Objects (AVOs)** are usually described with MPEG7. However this is not restrictive to apply this framework.
- **Learning Objects (LOs)** are described with IEEE LOM using the dmdSec of METS. Since LOM incorporates in its model entries for administrative information, the amdSec of METS is not separately used in this case for representing administrative metadata. The fileSec consisting of file elements is used to point to the LO's constituent parts (IOs) via identifiers.
- **Assessment Objects (AOs)** are also described with LOM metadata. While LOs containing IOs are built to fulfill specific learning objectives, AOs are used to evaluate learning objectives. IMS QTI [IMS QTI, 2005] descriptions are used for the representation of assessments that are referenced from the METS description.
- **Learning Components (LCs)** are also described with LOM via the dmdSec of METS. The structMap section is used to represent the LC's structure consisting of a hierarchy of activities (expressed with div) that can take place during the learning process using multiple devices. Each activity (div) is supported by a LO or an AO that is pointed to through file element via identifiers. A LC as a whole

and could reference using dmdSec elements some presentation info that is exploited at run-time to render the learning material in the target devices.

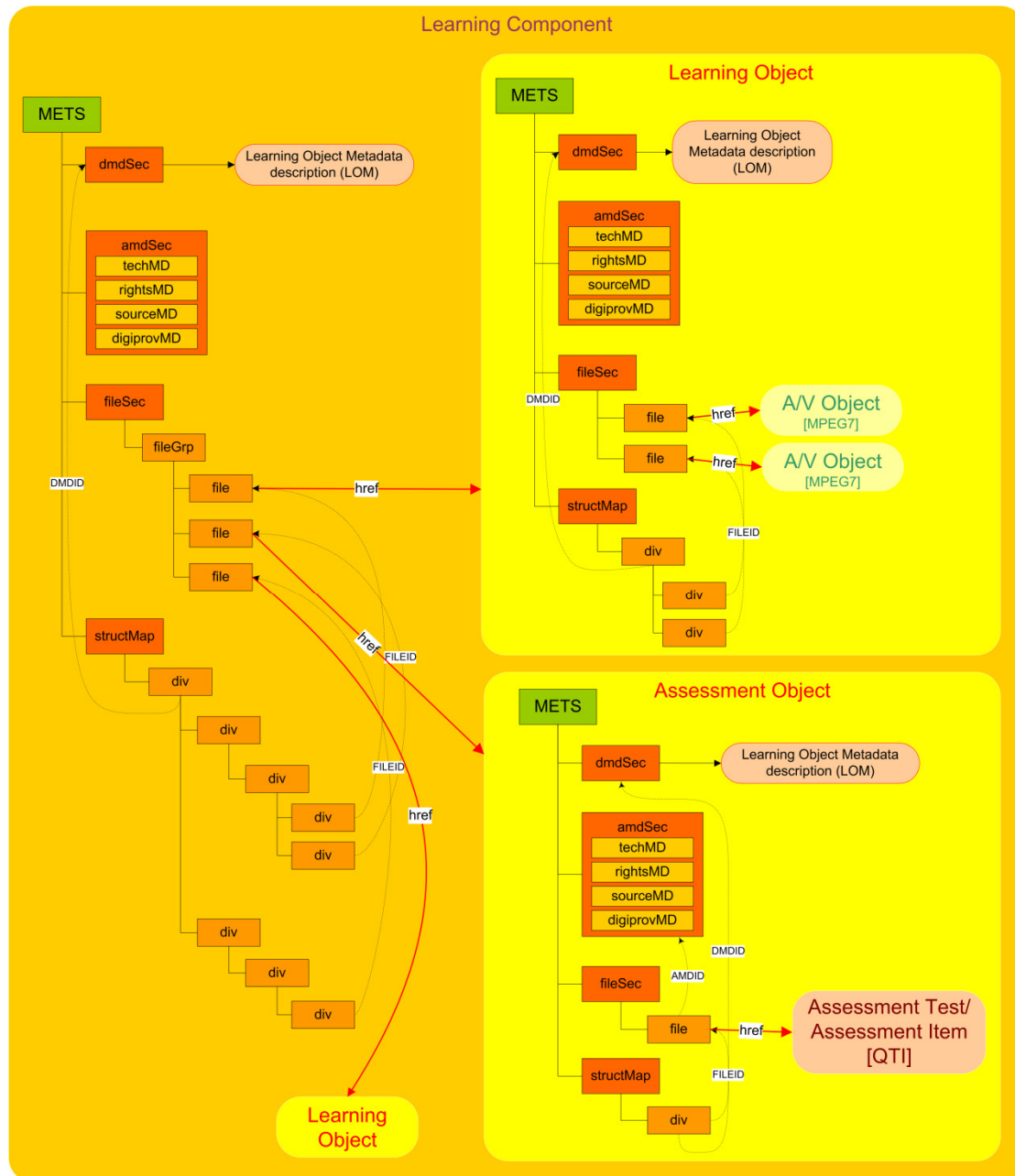


Figure 3.9 LCs, LOs, AOs and AVOs and their relations using METS according to the interoperability framework of this thesis

3.4.1.1. Audiovisual objects

The dominant standard for the description of audiovisual objects' characteristics is MPEG7, although the use of MPEG7 is not mandatory to apply the framework presented in this thesis. In Table 3.1 and Table 3.2 two simple examples of an image and a video segment focusing on their administrative characteristics are given in MPEG7. Of

course, MPEG7 is a very complicated scheme and an audiovisual object's description may contain much more information than this shown in these examples.

Table 3.1 Example of an image segment in MPEG7

```
<Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mpeg:mpeg7:schema:2001 Mpeg7-2001.xsd">
  <Description xsi:type="ContentEntityType">
    <MultimediaContent xsi:type="ImageType">
      <Image>
        <VisualDescriptor xsi:type="ColorStructureType" colorQuant="1">
          <Values>154 0 255 0 195 16 255 2 215 82 49 70 169 65
21 25 255 107 41 41 136 37 15 27 110 88 29 22 23 19 23
128</Values>
        </VisualDescriptor>
      </Image>
    </MultimediaContent>
    <MultimediaContent xsi:type="ImageType">
      <Image>
        <VisualDescriptor xsi:type="ColorStructureType" colorQuant="1">
          <Values>255 0 0 106 255 5 17 118 255 122 77 136 104 11
7 67 147 27 5 46 255 69 34 75 62 60 12 4 7 10 7
124</Values>
        </VisualDescriptor>
      </Image>
    </MultimediaContent>
    <MultimediaContent xsi:type="ImageType">
      <Image>
        <VisualDescriptor xsi:type="ColorStructureType" colorQuant="1">
          <Values>255 0 0 46 255 0 10 56 255 126 67 88 63 9 2
35 151 41 8 30 255 70 16 38 50 158 29 9 11 13 20
120</Values>
        </VisualDescriptor>
      </Image>
    </MultimediaContent>
  </Description>
</Mpeg7>
```

Table 3.2 Example of a video segment in MPEG7

```
<Mpeg7 xmlns="urn:mpeg:mpeg7:schema:2001"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:mpeg7="urn:mpeg:mpeg7:schema:2001"
xsi:schemaLocation="urn:mpeg:mpeg7:schema:2001 Mpeg7-2001.xsd">
  <Description xsi:type="ContentEntityType">
    <MultimediaContent xsi:type="VideoType">
      <Video id="VLO_TEST_1">
        <MediaLocator>
          <MediaUri>20041116_110000_CCTV4_NEWS3_CHN.mpg</MediaUri>
        </MediaLocator>
        <MediaTime>
          <MediaTimePoint>T00:00:00:0F30000</MediaTimePoint>
          <MediaDuration>PT00H28M19S29949N30000F</MediaDuration>
        </MediaTime>
        <TemporalDecomposition gap="false" overlap="false">
          <VideoSegment id="shot1_1">
            <MediaTime>
              <MediaTimePoint>T00:00:00:0F30000</MediaTimePoint>
            </MediaTime>
          </VideoSegment>
        </TemporalDecomposition>
      </Video>
    </MultimediaContent>
  </Description>
</Mpeg7>
```

```

        <MediaDuration>PT00H00M03S26116N30000F</MediaDuration>
      </MediaTime>
    </VideoSegment>
  </TemporalDecomposition>
</Video>
</MultimediaContent>
</Description>
</Mpeg7>

```

3.4.1.2. Learning objects

One important issue related to the concept of reusable learning objects is their description with metadata. The most popular metadata model used is the IEEE Learning Object Metadata (LOM) standard. It is possible to represent some pedagogical properties that can be matched with corresponding properties of Learner Profiles and Learning Designs in order to support an automated process for the construction of personalized learning experiences. However, the representation of several important pedagogical properties is not directly addressed in LOM and appropriate adaptations are needed to be able to incorporate this information. For example, the representation of Learning Objectives that capture the intended learning outcome of learning objects is not directly addressed and other elements of LOM, such as keywords or description are usually used to describe Learning Objectives. However, these simple text descriptions do not represent a formal way for defining learning objectives. Consequently, this approach presents a technical barrier because textual descriptions are not machine-readable and can not be exploited by personalization systems.

To address the shortcoming described above we need to define a more formal and pedagogically-sound way of expressing Learning Objectives, as well as their representations based on appropriate adaptation of existing LOM elements. Thus, as previously mentioned, we use Bloom's Taxonomy of educational and we define Learning Objectives as pairs consisting of a verb taken from the Bloom's taxonomy and a topic referencing a concept or individual of a domain ontology. In LOM, Learning Objectives can be expressed following the above approach using its classification element. The classification element describes where a learning object falls within a particular classification system. To define multiple classifications, there may be multiple instances of this category. Table 3.3 shows how this element can be adapted in order to represent a specific Learning Objective.

Table 3.3 Use of classification element of LOM to represent Learning Objectives

```

<lom:classification>
  <lom:purpose>
    <lom:value>educational objective</lom:value>
    <!-- Each educational objective is defined as verb from Bloom's
Taxonomy)+ Topic (Ontology Concept/Individual) -->
  </lom:purpose>
  <lom:taxonPath>
  <lom:source>

```

```

    <lom:string
language="en">http://somehost/bloomstaxonomy.owl</lom:string>
    <!-- The URL of the ontology containing the Bloom's Taxonomy Verbs-->
</lom:source>
    <lom:taxon>
    <lom:entry>
    <lom:string language="en">define</lom:string>
    <!-- The verb of the learning objective-->
    </lom:entry>
    </lom:taxon>
</lom:taxonPath>
<lom:taxonPath>
    <lom:source>
    <lom:string
language="en">http://somehost/databasesdomain.owl</lom:string>
    <!-- The URL of the target ontology -->
    </lom:source>
    <lom:taxon>
    <lom:entry>
    <lom:string language="en">Databases</lom:string>
    <!-- The topic of the learning objective (a Concept of Iconography
Ontology)-->
    </lom:entry>
    </lom:taxon>
    </lom:taxonPath>
</lom:classification>

```

Educational level has been also considered as an important parameter when performing personalization. In order to be able to retrieve learning objects that are appropriate in terms of the educational level, this info should be incorporated in their descriptions. The only appropriate element of LOM that allows for the inclusion of educational levels is the classification element. Table 3.4 shows how the classification element of LOM is used in order to include info about the intended educational level of the current learning object:

Table 3.4 Use of classification element of LOM to represent Educational Level

```

<lom:classification>
    <lom:purpose>
    <lom:value>educational level</lom:value>
    </lom:purpose>
    <lom:taxonPath>
    <lom:source>
    <lom:string
language="en">http://somehost/educationallevels.owl</lom:string>
    <!-- The URL of the selected taxonomy of educational levels-->
    </lom:source>
    <lom:taxon>
    <lom:entry>
    <lom:string language="en">Primary</lom:string>
    <!-- The educational level for which this learning object is
appropriate-->
    </lom:entry>
    </lom:taxon>
    </lom:taxonPath>
</lom:classification>

```

The difficulty and the provider of a Learning Object are represented in <educational>/<difficulty> and <lifecycle>/<contribute> elements of LOM respectively.

In order to perform adaptive selection of learning objects according to learning styles, this framework uses the following elements of LOM, as the most appropriate ones for this purpose:

- <learningResourceType>
- <interactivityType>
- <interactivityLevel>
- <semanticDensity>

These elements are described in detail in Table 3.5.

Table 3.5 LOM elements used in the framework for the adaptive selection of learning objects according to the learning style [IEEE LOM, 2002]

Nr	Name	Explanation	Value Space	Example
5	educational			
5.1	interactivityType	<p>Predominant mode of learning supported by this learning object.</p> <p>"Active" learning (e.g., learning by doing) is supported by content that directly induces productive action by the learner. An active learning object prompts the learner for semantically meaningful input or for some other kind of productive action or decision, not necessarily performed within the learning object's framework. Active documents include simulations, questionnaires, and exercises.</p> <p>"Expositive" learning (e.g., passive learning) occurs when the learner's job mainly consists of absorbing the content</p>	active expositive mixed	<p>active documents (with learner's action):</p> <ul style="list-style-type: none"> · simulation (manipulates, controls or enters data or parameters); · questionnaire (chooses or writes answers); · exercise (finds solution); · problem statement (writes solution). <p>expositive documents:</p> <ul style="list-style-type: none"> · hypertext document (reads, navigates); · video (views, rewinds, starts, stops); · graphical material (views); · audio material (listens, rewinds, starts, stops). <p>mixed document:</p> <ul style="list-style-type: none"> · hypermedia document with embedded simulation applet.

		<p>exposed to him (generally through text, images or sound). An expositive learning object displays information but does not prompt the learner for any semantically meaningful input. Expositive documents include essays, video clips, all kinds of graphical material, and hypertext documents.</p> <p>When a learning object blends the active and expositive interactivity types, then its interactivity type is "mixed".</p> <p>NOTE:--Activating links to navigate in hypertext documents is not considered to be a productive action.</p>		
5.2	learningResourceType	<p>Specific kind of learning object. The most dominant kind shall be first.</p> <p>NOTE:--The vocabulary terms are defined as in the OED:1989 and as used by educational communities of practice.</p>	<p>exercise simulation questionnaire diagram figure graph index slide table narrative text exam experiment problem statement self assessment lecture</p>	
5.3	interactivityLevel	<p>The degree of interactivity characterizing this learning object. Interactivity in this context refers to the degree to which the learner can influence the aspect or behavior of the learning object.</p> <p>NOTE 1:--Inherently, this scale is meaningful within the context of a</p>	<p>very low low medium high very high</p>	<p>NOTE 2:--Learning objects with 5.1:Educational.InteractivityType="active" may have a high interactivity level (e.g., a simulation environment endowed with many controls) or a low interactivity level (e.g., a written set of instructions that solicit an activity). Learning objects with 5.1:Educational.InteractivityT</p>

		community of practice.		type="expositive" may have a low interactivity level (e.g., a piece of linear, narrative text produced with a standard word processor) or a medium to high interactivity level (e.g., a sophisticated hyperdocument, with many internal links and views).
5.4	semanticDensity	<p>The degree of conciseness of a learning object. The semantic density of a learning object may be estimated in terms of its size, span, or --in the case of self-timed resources such as audio or video-- duration. The semantic density of a learning object is independent of its difficulty. It is best illustrated with examples of expositive material, although it can be used with active resources as well.</p> <p>NOTE 1:--Inherently, this scale is meaningful within the context of a community of practice.</p>	<p>very low low medium high very high</p>	<p><i>Active documents:</i> user interface of a simulation - low semantic density: a screen filled up with explanatory text, a picture of a combustion engine, and a single button labeled "Click here to continue" - high semantic density: screen with short text, same picture, and three buttons labeled "Change compression ratio", "Change octane index", "Change ignition point advance"</p> <p><i>Expositive documents:</i> medium difficulty text document medium semantic density: "The class of Marsupial animals comprises a number of relatively primitive mammals. They are endowed with a short placentation, after which they give birth to a larva. The larva thereafter takes refuge in the mother's marsupium, where it settles to finish its complete development." high semantic density: "Marsupials are primitive mammals, with short placentation followed by the birth of larva, which thereafter takes refuge in the marsupium to finish its development."</p> <p>easy video document - low semantic density: The full recorded footage of a conversation between two experts on the differences between Asian and African elephants; 30 minutes</p>

				<p>duration.</p> <ul style="list-style-type: none"> - high semantic density: An expertly edited abstract of the same conversation; 5 minutes duration difficult mathematical notation - medium semantic density: The text representation of the theorem: For any given set j, it is always possible to define another set y, which is a superset of j. - very high semantic density: The symbolic representation (formula) of the theorem ("$j \subseteq y: y \in j$")
9	Classification (Used as proposed in this thesis in order to form Learning Objectives)	This category describes where this learning object falls within a particular classification system. To define multiple classifications, there may be multiple instances of this category.		e.g. define Biology

The possible values of learningResourceType indicating the type of a learning object are explained in detail in Table 3.6.

Table 3.6 LOM learningResourceType values [IEEE LOM, 2002]

exercise	An exercise is "the use of or method of using; a task prescribed or performed for the sake of attaining proficiency, for training either body or mind, or as an exhibition or test of proficiency or skill". Use for any learning resource that is associated with a planned sequence of actions that are not evaluated and not part of a simulation (e.g., critical thinking activity, brainstorming, assignment, tutorial, worksheet). Note that some alternative or custom vocabularies may classify educational resource types as types of educational activities. In such cases, the LOM value of Exercise may be the closest equivalent value that is available for any and all values from such vocabularies.
simulation	A simulation is "the technique of imitating the behavior of some situation or process (whether economic, military, mechanical, etc.) by means of a suitably analogous situation or apparatus".
questionnaire	A questionnaire is "a list of questions by which information is sought from a selected group, usually for statistical analysis".
diagram	A diagram is "an illustrative figure which, without representing the exact appearance of a resource, gives an outline or general scheme of it, so as to exhibit the shape and relations of its various parts; a set of lines, marks, or tracings which represent symbolically the course or results of any action or process, or the variations which characterize it". Use figure as a preferred container term.
figure	A figure is "the image, likeness, or representation of something material or immaterial". Use for any learning resource that consists of or contains visual representation(s)

	other than text, including photographs, maps, video, animations, and visual hypermedia.
graph	A graph is "a kind of symbolic diagram (used in Chemistry, Mathematics, etc.) in which a system of connections is expressed by spots or circles, some pairs of which are colligated by one or more lines". Use figure as a preferred container term.
index	An index is "a reference list; an alphabetical list". Use for any resource that constitutes a dataset, collection, list of links, references or pointers, or a searchable database (e.g., clearinghouse, search engine, glossary, reference). This value does not include a list of objectives or goals.
slide	A slide is "a photographic transparency for use in a slide projector". Use figure as a preferred container term.
table	A table is "an arrangement in columns and lines...as the multiplication table, tables of weights and measures, a table of logarithms, astronomical tables, insurance tables, time-tables, etc.".
narrative text	A narrative text is "an account or narration; a history, tale, story, recital (of facts, etc.) that is a portion of the contents of a manuscript or printed book, or of a page, which constitutes the original matter, as distinct from the notes or other critical appendages". Use for any learning resource that consists of or contains text (including hypertext, and text-based communications), except where that text is a listing (use Index) or serves an evaluative purpose (use Exam).
exam	An exam is "the process of testing, by questions oral or written, the knowledge or ability of pupils, or of candidates for office, degrees, etc.". Use for any learning resource whose primary purpose is the evaluation of the user's actions or input (e.g., assessment item, quiz).
experiment	An experiment is "an action or operation undertaken in order to discover something unknown, to test a hypothesis, or establish or illustrate some known truth". Use Exercise as a preferred container term when the learning resource does not specifically correspond to or contain an experiment
problem statement	A problem statement is "a written or oral communication setting forth... a difficult or puzzling question proposed for solution". Use for any learning resource that helps define instruction (e.g., objectives, outcomes, lesson plan, problem set, syllabus, prerequisites, attractor, curriculum)
self-assessment	A self-assessment is an "assessment or evaluation of oneself, one's actions or attitudes by oneself". Use Exam as a preferred container term.
lecture	A lecture is "a discourse given before an audience upon a given subject, usually for the purpose of instruction". Use the value narrative text instead of lecture if the lecture is in textual form. Use for any audio or sound recording

Using the above elements in learning objects' metadata for their adaptive selection according to learning styles, learning objects remain independent from the learning style approach that is used in the upper levels. This is an advantage of this framework in contrast with other approaches mentioned in Chapter 2, where the learning style value for which a learning object is appropriate has been incorporated in its metadata. Embedding a specific learning style approach in learning objects' metadata prohibits the exploitation of those learning objects in other learning style categorizations.

In Table 3.7 an example of a Learning Object is given. The structural map (structMap) outlines a hierarchical structure for the original object being encoded, using a series of nested div elements. Only leaf elements can contain references to files (fptr). In this case the object being encoded is a learning object which is considered as a collection of digital objects, each one pointing to its actual content through fileSec. Learning Object's metadata are enclosed in dmdSec. Moreover, the Learning Object could contain some administrative metadata in amdSec (e.g. rights). However, for simplicity, in the above example we do not present administrative metadata in detail, since they are not important in the application of the personalization framework presented here.

Table 3.7 Example of a Learning Object represented with METS

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<mets xmlns="http://www.loc.gov/METS/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:lom="http://ltsc.ieee.org/xsd/LOM" ID="f6052f9d-c22b-11dd-af70-
33b2774ad291" TYPE="String">
  <metsHdr CREATEDATE="2008-12-04T19:03:21" LASTMODDATE="2008-12-
07T15:26:55">
    <agent ROLE="CREATOR" TYPE="INDIVIDUAL">
      <name>Polyxeni Arapi</name>
      <note>Any additional information regarding the agent's
activities with respect to the METS document.</note>
    </agent>
    <agent ROLE="ARCHIVIST" TYPE="ORGANIZATION">
      <name>TUC/MUSIC</name>
      <note>Any additional information regarding the agent's
activities with respect to the METS document.</note>
    </agent>
    <altRecordID ID="altRecordVersion_17"/>
  </metsHdr>
  <dmdSec ID="LOM">
    <mdWrap LABEL="LOM metadata Record" MDTYPE="LOM"
MIMETYPE="text/xml">
      <xmlData>
        <lom xmlns="http://ltsc.ieee.org/xsd/LOM">
          <general>
            <title>
              <string language="en">The Virgin Hodegetria
</string>
            </title>
            <language>en-us</language>
            <description>
              <string language="en">This learning object
presents the iconography of the Virgin Hodegetria.</string>
            </description>
            <keyword>
              <string language="en">Bulgarian Iconography, The
Virgin Hodegetria, Greek Iconography</string>
            </keyword>
            <coverage>
              <string language="en">Bulgarian
Iconography</string>
            </coverage>
          </general>
        </lom>
      </xmlData>
    </mdWrap>
  </dmdSec>
</mets>
```

```

        <structure>
            <source>LOMv1.0</source>
            <value>collection</value>
        </structure>
        <aggregationLevel>
            <source>LOMv1.0</source>
            <value>2</value>
        </aggregationLevel>
    </general>
    <lifeCycle>
        <version>
            <string language="en">1</string>
        </version>
        <status>
            <source>LOMv1.0</source>
            <value>final</value>
        </status>
        <contribute>
            <role>
                <source>LOMv1.0</source>
                <value>author</value>
            </role>
            <entity>BEGIN:VCARD
FN:Maria Marinova
VERSION:3.0
TEL:+1-919-555-7878
TITLE:Area Administrator\,Assistant
EMAIL;TYPE=INTERNET:maria.b.marinova@gmail.com
END:VCARD</entity>

                <date>
                    <dateTime>2008-08-23</dateTime>
                    <description>
                        <string language="en">date of
contribution</string>
                    </description>
                </date>
            </contribute>

        </lifeCycle>
        <metaMetadata>
            <identifier>
                <catalog>IOR</catalog>
                <entry>f6052f9d-c22b-11dd-af70-
33b2774ad291</entry>
            </identifier>
            <contribute>
                <role>
                    <source>LOMv1.0</source>
                    <value>creator</value>
                </role>
                <entity>BEGIN:VCARD
FN:Maria Marinova
VERSION:3.0
TEL:+1-919-555-7878
TITLE:Area Administrator\,Assistant
EMAIL;TYPE=INTERNET:maria.b.marinova@gmail.com
END:VCARD</entity>

                <date>
                    <dateTime>2008-08-23</dateTime>

```

```

        <description>
            <string language="en">date of
contribution</string>
        </description>
    </date>
</contribute>
<metadataSchema>LOMv1.0</metadataSchema>
<metadataSchema>SCORM_CAM_v1.3</metadataSchema>
<language>en</language>
</metaMetadata>
<technical>
    <format>text/html</format>
    <size>1024</size>
    <location>LOGOS LO repository</location>
    <requirement>
        <orComposite>
            <type>
                <source>LOMv1.0</source>
                <value>browser</value>
            </type>
            <name>
                <source>LOMv1.0</source>
                <value>ms-internet explorer</value>
            </name>
            <minimumVersion>5.0</minimumVersion>
            <maximumVersion>6.0</maximumVersion>
        </orComposite>
    </requirement>
    <installationRemarks>
        <string language="en"/>
    </installationRemarks>
    <otherPlatformRequirements>
        <string language="en"/>
    </otherPlatformRequirements>
    <duration>
        <duration>PT1H30M</duration>
        <description>
            <string language="en">This activity requires
the client browser to have a Macromedia Flash plugin installed.</string>
        </description>
    </duration>
</technical>
<educational>
    <interactivityType>
        <source>LOMv1.0</source>
        <value>expositive</value>
    </interactivityType>
    <learningResourceType>
        <source>LOMv1.0</source>
        <value>narrative text</value>
    </learningResourceType>
    <interactivityLevel>
        <source>LOMv1.0</source>
        <value>very low</value>
    </interactivityLevel>
    <semanticDensity>
        <source>LOMv1.0</source>
        <value>medium</value>
    </semanticDensity>

```

```

<intendedEndUserRole>
  <source>LOMv1.0</source>
  <value>learner</value>
</intendedEndUserRole>
<context>
  <source>LOMv1.0</source>
  <value>training</value>
</context>
<typicalAgeRange>
  <string language="en">18-24</string>
</typicalAgeRange>
<difficulty>
  <source>LOMv1.0</source>
  <value>medium</value>
</difficulty>
<typicalLearningTime>
  <duration>PT45M</duration>
  <description>
    <string language="en">A description</string>
  </description>
</typicalLearningTime>
<description>
  <string language="en"/>
</description>
<language>en</language>
</educational>
<rights>
  <cost>
    <source>LOMv1.0</source>
    <value>no</value>
  </cost>
  <copyrightAndOtherRestrictions>
    <source>LOMv1.0</source>
    <value>yes</value>
  </copyrightAndOtherRestrictions>
  <description>
    <string language="en">All copyrights of the
digitized objects in this learning object are reserved by IMI-BAS.</string>
  </description>
</rights>
<classification>
  <purpose>
    <value>educational level</value>
  </purpose>
  <taxonPath>
    <source>
      <string language="en">Educational level
taxonomy</string>
    </source>
    <taxon>
      <entry>
        <string language="en">Further</string>
      </entry>
    </taxon>
  </taxonPath>
</classification>
<classification>
  <purpose>
    <value>educational objective</value>

```

```

        </purpose>
        <taxonPath>
            <source>
                <string language="en">Bloom's
taxonomy</string>
            </source>
            <taxon>
                <entry>
                    <string language="en">analyze</string>
                </entry>
            </taxon>
        </taxonPath>
        <taxonPath>
            <source>
                <string language="en">icons-stable-
061107.xml</string>
            </source>
            <taxon>
                <entry>
                    <string language="en">Image of the
Virgin Mary#The Virgin Hodegetria</string>
                </entry>
            </taxon>
        </taxonPath>
        <keyword>
            <string language="en"/>
        </keyword>
        <description>
            <string language="en"/>
        </description>
    </classification>
</lom>
</xmlData>
</mdWrap>
</dmdSec>

<fileSec>
    <fileGrp>
        <file ID="FILE1_1534" MIMETYPE=" text/html" SIZE="100">
            <FLocat LOCTYPE="URN" xlink:href="22d544-3996-4184-82e2-
3139c44a08bc" xlink:type="simple"/>
        </file>
        <file ID="FILE2_2634" MIMETYPE="text/html" SIZE="120">
            <FLocat LOCTYPE="URN" xlink:href="a7dcb3-7190-42e7-aeb5-
eb390be83410" xlink:type="simple"/>
        </file>
    </fileGrp>
</fileSec>

<structMap>
    <div DMDID="LOM" ID="DIV1" LABEL="The Virgin Hodegetria"
TYPE="learningobject">
        <div ID="DIV1_1228410512906" LABEL="The Holy Mother of God"
TYPE="digitalobject">
            <fptr FILEID="FILE1_1534"/>
        </div>
        <div ID="DIV1_1232023901468" LABEL="The Virgin of the Passion"
TYPE="digitalobject">
            <fptr FILEID="FILE2_2634"/>
        </div>
    </div>
</structMap>

```

```

        </div>
    </div>
</structMap>
</mets>

```

3.4.1.3. Assessment objects

Knowledge is not permanent and not static. As time goes by, knowledge upon specific topics is fading out or it is further improved. This is a matter of how human mind and memory works and depends on several factors. In order to be able for an eLearning system or an instructor to appropriately adapt the learning process to the current each time Learner's needs, the information about the knowledge of the Learner upon the relevant with Learner's goals topics should be updated.

A usual and pretty precise method used not only in eLearning but also in traditional formal approaches of instruction to evaluate the satisfaction of Learning Objectives (previous knowledge) is using tests.

In this framework we argue that ideally for each Learning Objective there must be at least one Assessment Object being able to evaluate it. Learning Objects are built in order to fulfil certain learning objectives, while Assessment Objects are built and used to assess the satisfaction of certain learning objectives. Assessment Objects could be simple questions (Assessment Items) or complex questionnaires consisting of Assessment Items (Assessment Tests) described with educational metadata. Tests or simple questions in the form of Assessment Objects can be given to Learners before preparing a personalized learning experience for them (pre-test), in order to identify the previous knowledge of the Learner on specific topics (the satisfaction value of the related Learning Objectives) to create this way a more efficient learning experience for them. They can be also given at the end of a learning experience in order to update the satisfaction status and evaluate how much effective was the learning experience for them⁴.

Descriptions according to the IMS Question & Test Interoperability specification [IMS QTI, 2005] are used for the representation of Assessment Items and Assessment Tests. The IMS Question & Test Interoperability specification describes a data model for the representation of question (assessmentItem) and test (assessmentTest) data and their corresponding results reports. Therefore, the specification enables the exchange of items, tests and results data between authoring tools, item banks, test constructional tools, learning systems and assessment delivery systems.

An Assessment Item (AI) according to IMS QTI specification is the smallest exchangeable object that can be used for assessment. An assessment item encompasses

⁴ Regarding the measurement of the effectiveness of a learning experience, tests only are many times not enough in order to extract useful conclusions, but the direct feedback of Learners can be proven more useful using appropriate questionnaires.

the information that is presented to a candidate and information about how to score the item. Scoring takes place when candidate responses are transformed into outcomes by response processing rules. An item is more than a 'Question' in that it contains the question and instructions to be presented, the responseProcessing to be applied to the candidate's response(s) and the Feedback that may be presented (including hints and solutions). In this specification items are represented by the assessmentItem class and the term assessment item is used interchangeably for item. An example of an Assessment Item is given in Table 3.8.

Table 3.8 Example of an Assessment Item represented with IMS QTI

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<assessmentItem xmlns="http://www.imsglobal.org/xsd/imsqti_v2p1"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" adaptive="false"
identifier="e42d4e3f-c4b2-11dd-8f86-cfd665ef03c8" timeDependent="false"
title="The meaning of the term Hodegetria">
  <responseDeclaration baseType="identifier" cardinality="multiple"
identifier="RESPONSE">
    <correctResponse>
      <value>A1</value>
      <value>A4</value>
    </correctResponse>
  </responseDeclaration>
  <outcomeDeclaration baseType="integer" cardinality="multiple"
identifier="SCORE"/>
  <outcomeDeclaration baseType="identifier" cardinality="multiple"
identifier="FEEDBACK"/>
  <itemBody>
    <choiceInteraction maxChoices="1" responseIdentifier="RESPONSE"
shuffle="false">
      <prompt>What does "Hodegetria" mean in relation to the Holy
Mother of God?</prompt>
      <simpleChoice identifier="A1">Guide of the Church<feedbackInline
identifier="A1" outcomeIdentifier="FEEDBACK" showHide="show">It is
correct.</feedbackInline>
      </simpleChoice>
      <simpleChoice identifier="A2">Queen of Heaven<feedbackInline
identifier="A2" outcomeIdentifier="FEEDBACK"
showHide="show">Incorrect.</feedbackInline>
      </simpleChoice>
      <simpleChoice identifier="A3">Tender Touch<feedbackInline
identifier="A3" outcomeIdentifier="FEEDBACK"
showHide="show">Incorrect.</feedbackInline>
      </simpleChoice>
      <simpleChoice identifier="A4">Pointer of the Way<feedbackInline
identifier="A4" outcomeIdentifier="FEEDBACK" showHide="show">It is
correct.</feedbackInline>
      </simpleChoice>
    </choiceInteraction>
  </itemBody>
  <responseProcessing
template="http://www.imsglobal.org/question/qti_v2p1/rptemplates/map_respons
e"/>
</assessmentItem>
```

An Assessment Test (AT) according to the IMS QTI specification is an organized collection of Items that are used to determine the values of the outcomes (e.g. level of mastery) when measuring the performance of a candidate in a particular domain. An Assessment Test contains all of the necessary instructions to enable the sequencing of the items and the calculation of the outcome values (e.g. the final test score). An example of an Assessment Test is given in Table 3.9.

Table 3.9 Example of an Assessment Test expressed with IMS QTI

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<assessmentTest xmlns="http://www.imsglobal.org/xsd/imsqti_v2p1"
  identifier="d6a13306-fd37-11dd-8da8-3bcb55ee78d9" title="Analyze Virgin
  Hodegetria Image" toolVersion="1.5" toolname="COE"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.imsglobal.org/xsd/imsqti_v2p1
  http://www.imsglobal.org/xsd/imsqti_v2p1.xsd">
  <timeLimits/>
  <testPart identifier="id0157bf4c_TESTPART" navigationMode="linear"
  submissionMode="individual">
    <itemSessionControl allowComment="false" allowReview="false"
    allowSkipping="false" maxAttempts="1" showFeedback="true"
    showSolution="true" validateResponses="true"/>
    <timeLimits/>
    <assessmentSection identifier="id01f1e39b" title="Group" visible="true">
      <itemSessionControl allowComment="false" allowReview="false"
      allowSkipping="false" maxAttempts="1" showFeedback="true"
      showSolution="true" validateResponses="true"/>
      <timeLimits/>
      <selection select="1" withReplacement="false"/>
      <ordering shuffle="false"/>
      <assessmentItemRef href="ai:e42d4e3f-c4b2-11dd-8f86-cfd665ef03c8"
      identifier="id0195ff24"/>
      <assessmentItemRef href="ai:4e3343b0-c4b5-11dd-8f86-cfd665ef03c8"
      identifier="id00a1c582"/>
    </assessmentSection>
  </testPart>
</assessmentTest>
```

METS is used again, according to the framework presented in this thesis, to integrate those IMS QTI descriptions (Assessments Items or Assessment Tests) with educational metadata (LOM) and administrative metadata forming Assessment Objects. So, an Assessment Object corresponds to a METS representation including the reference to the corresponding Assessment Item/Test QTI description and its educational and administrative metadata. An example of an Assessment Item Object is given in Table 3.10.

Table 3.10 Example of an Assessment Item Object represented with METS

```
<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<mets xmlns="http://www.loc.gov/METS/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:lom="http://ltsc.ieee.org/xsd/LOM" ID="e42d4e3f-c4b2-11dd-8f86-
  cfd665ef03c8" TYPE="String">
  <metsHdr CREATEDATE="2008-12-08T00:44:47" LASTMODDATE="2009-02-
```



```

17T11:22:03">
  <agent ROLE="CREATOR" TYPE="INDIVIDUAL">
    <name>Polyxeni Arapi</name>
    <note>Any additional information regarding the agent's
activities with respect to the METS document.</note>
  </agent>
  <agent ROLE="ARCHIVIST" TYPE="ORGANIZATION">
    <name>TUC/MUSIC</name>
    <note>Any additional information regarding the agent's
activities with respect to the METS document.</note>
  </agent>
  <altRecordID ID="altRecordVersion_6"/>
</metsHdr>

<dmdSec ID="LOM">
  <mdWrap LABEL="LOM metadata Record" MDTYPE="LOM"
MIMETYPE="text/xml">
    <xmlData>
      <lom xmlns="http://ltsc.ieee.org/xsd/LOM">
        <general>
          <title>
            <string language="en">The meaning of the term
"Hodegetria"</string>
          </title>
          <language>en-us</language>
          <description>
            <string language="en">This item assesses the
level of understanding of the new terms.</string>
          </description>
          <keyword>
            <string language="en">Hodegetria, Holy Mother of
God, </string>
          </keyword>
          <coverage>
            <string language="en">Bulgarian
Iconography</string>
          </coverage>
          <structure>
            <source>LOMv1.0</source>
            <value>collection</value>
          </structure>
          <aggregationLevel>
            <source>LOMv1.0</source>
            <value>1</value>
          </aggregationLevel>
        </general>
        <lifeCycle>
          <version>
            <string language="en">1</string>
          </version>
          <status>
            <source>LOMv1.0</source>
            <value>final</value>
          </status>
          <contribute>
            <role>
              <source>LOMv1.0</source>
              <value>author</value>
            </role>

```

```

                                <entity>BEGIN:VCARD
FN:Maria Marinova
N:Friday;Joe
VERSION:3.0
TEL:+1-919-555-7878
TITLE:Area Administrator\,Assistant
EMAIL;TYPE=INTERNET:maria.b.marinova@gmail.com
END:VCARD</entity>

                                <date>
                                <dateTime>2001-08-23</dateTime>
                                <description>
                                <string language="en">date of
contribution</string>
                                </description>
                                </date>
                                </contribute>
                                <contribute>
                                <role>
                                <source>LOMv1.0</source>
                                <value>author</value>
                                </role>
                                <entity>BEGIN:VCARD
FN:Lilia Pavlova-Draganova
N:Friday;Joe
VERSION:3.0
TEL:+1-919-555-7878
TITLE:Area Administrator\,Assistant
EMAIL;TYPE=INTERNET:lilia_pavlova@hotmail.com
END:VCARD</entity>

                                <date>
                                <dateTime>2001-08-23</dateTime>
                                <description>
                                <string language="en">date of
contribution</string>
                                </description>
                                </date>
                                </contribute>
                                </lifeCycle>
                                <metaMetadata>
                                <identifier>
                                <catalog>AOR</catalog>
                                <entry>e42d4e3f-c4b2-11dd-8f86-
cfd665ef03c8</entry>
                                </identifier>
                                <contribute>
                                <role>
                                <source>LOMv1.0</source>
                                <value>creator</value>
                                </role>
                                <entity>BEGIN:VCARD
FN:Joe Friday
N:Friday;Joe
VERSION:3.0
TEL:+1-919-555-7878

```

```
TITLE:Area Administrator\,Assistant

EMAIL;TYPE=INTERNET:jfriday@host.com

END:VCARD</entity>

        <date>
            <dateTime>2001-08-23</dateTime>
            <description>
                <string language="en">date of
contribution</string>
            </description>
        </date>
    </contribute>
    <metadataSchema>LOMv1.0</metadataSchema>
    <metadataSchema>SCORM_CAM_v1.3</metadataSchema>
    <language>en</language>
</metaMetadata>
<technical>
    <format>text/html</format>
    <size>0</size>
    <location>LOGOS LO repository</location>
    <requirement>
        <orComposite>
            <type>
                <source>LOMv1.0</source>
                <value>browser</value>
            </type>
            <name>
                <source>LOMv1.0</source>
                <value>ms-internet explorer</value>
            </name>
            <minimumVersion>5.0</minimumVersion>
            <maximumVersion>6.0</maximumVersion>
        </orComposite>
    </requirement>
    <installationRemarks>
        <string language="en"/>
    </installationRemarks>
    <otherPlatformRequirements>
        <string language="en"/>
    </otherPlatformRequirements>
    <duration>
        <duration>PT1H30M</duration>
        <description>
            <string language="en">This activity requires
the client browser to have a Macromedia Flash plugin installed.</string>
        </description>
    </duration>
</technical>
<educational>
    <interactivityType>
        <source>LOMv1.0</source>
        <value>active</value>
    </interactivityType>
    <learningResourceType>
        <source>LOMv1.0</source>
        <value>exercise</value>
    </learningResourceType>
    <interactivityLevel>
```

```

        <source>LOMv1.0</source>
        <value>low</value>
    </interactivityLevel>
    <semanticDensity>
        <source>LOMv1.0</source>
        <value>medium</value>
    </semanticDensity>
    <intendedEndUserRole>
        <source>LOMv1.0</source>
        <value>learner</value>
    </intendedEndUserRole>
    <context>
        <source>LOMv1.0</source>
        <value>higher education</value>
    </context>
    <typicalAgeRange>
        <string language="en">18-24</string>
    </typicalAgeRange>
    <difficulty>
        <source>LOMv1.0</source>
        <value>medium</value>
    </difficulty>
    <typicalLearningTime>
        <duration>PT5M</duration>
        <description>
            <string language="en">A description</string>
        </description>
    </typicalLearningTime>
    <description>
        <string language="en"/>
    </description>
    <language>en</language>
</educational>
<rights>
    <cost>
        <source>LOMv1.0</source>
        <value>no</value>
    </cost>
    <copyrightAndOtherRestrictions>
        <source>LOMv1.0</source>
        <value>yes</value>
    </copyrightAndOtherRestrictions>
    <description>
        <string language="en">Contact LOGOS</string>
    </description>
</rights>
<classification>
    <purpose>
        <value>educational level</value>
    </purpose>
    <taxonPath>
        <source>
            <string language="en">Educational level
taxonomy</string>
        </source>
        <taxon>
            <entry>
                <string language="en">Further</string>
            </entry>

```

```

        </taxon>
    </taxonPath>
    <taxonPath>
        <source>
            <string language="en"/>
        </source>
    </taxon>
        <entry>
            <string language="en"/>
        </entry>
    </taxon>
</taxonPath>
<keyword>
    <string language="en"/>
</keyword>
<description>
    <string language="en"/>
</description>
</classification>
<classification>
    <purpose>
        <value>educational objective</value>
    </purpose>
    <taxonPath>
        <source>
            <string language="en">Bloom's
taxonomy</string>
        </source>
    </taxon>
        <entry>
            <string language="en">interpret</string>
        </entry>
    </taxon>
</taxonPath>
<taxonPath>
    <source>
        <string language="en">icons-stable-
061107.xml</string>
    </source>
    <taxon>
        <entry>
            <string language="en">Image of the
Virgin Mary#The Virgin Hodegetria</string>
        </entry>
    </taxon>
</taxonPath>
<keyword>
    <string language="en"/>
</keyword>
<description>
    <string language="en"/>
</description>
</classification>
</lom>
</xmlData>
</mdWrap>
</dmdSec>

<fileSec>

```

```

<fileGrp>
  <file ID="MH_FILE_1" MIMETYPE="text/x-imsqti-item-xml">
    <FLocat LOCTYPE="URN" xlink:href="e42d4e3f-c4b2-11dd-8f86-
cfd665ef03c8"/>
  </file>
</fileGrp>
</fileSec>

<structMap>
  <div DMDID="LOM" ID="MH_DIV" LABEL="The meaning of the term
'&quot;Hodegetria&quot;'" TYPE="assessmentitemobject">
    <fprr FILEID="MH_FILE_1"/>
  </div>
</structMap>
</mets>

```

Similarly, the METS representation of an Assessment Test Object is presented in Table 3.11, including the reference to the corresponding Assessment Test QTI description and its educational and administrative metadata.

Table 3.11 Example of an Assessment Test Object. An Assessment Test Object is an Assessment Test described with metadata. METS is used again to represent the Assessment Test Object and LOM for its metadata. The actual content of the Assessment is represented with IMS QTI and pointed to by the METS document

```

<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<mets xmlns="http://www.loc.gov/METS/" ID="d6a13306-fd37-11dd-8da8-
3bcb55ee78d9" TYPE="ATO" xmlns:LOM="http://ltsc.ieee.org/xsd/LOM"
xmlns:imsss="http://www.imslobal.org/xsd/imsss"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.loc.gov/METS/
http://www.loc.gov/standards/mets/mets.xsd http://ltsc.ieee.org/xsd/LOM
http://standards.ieee.org/reading/ieee/downloads/LOM/lomv1.0/xsd/lom.xsd
http://www.imslobal.org/xsd/imsss imsss_v1p0.xsd">

<metsHdr CREATEDATE="2001-12-17T09:30:47" LASTMODDATE="2001-12-17T09:30:47-
05:00">
  <agent ROLE="CREATOR" TYPE="INDIVIDUAL">
    <name>no information</name>
    <note>no information</note>
  </agent>
<altRecordID ID="altRecordVersion_4"/></metsHdr>

<dmdSec ID="LOM">
<mdWrap LABEL="LOM metadata Record" MDTYPE="LOM" MIMETYPE="text/xml">
<xmlData>
<lom xmlns="http://ltsc.ieee.org/xsd/LOM">
  <general>
    <title>
      <string language="en">Analyze Virgin Hodegetria Image</string>
    </title>
    <language>en</language>
    <description>
      <string language="en">Test the ability of the Learner to analyze
Virgin Hodegetria Image</string>
    </description>
  </general>
</lifeCycle>

```

```
<version>
  <string language="en">1.0</string>
</version>
<status>
  <source>LOMv1.0</source>
  <value>final</value>
</status>
<contribute>
  <role>
    <source>LOMv1.0</source>
    <value>author</value>
  </role>
  <entity>BEGIN:vCardArapi;PolyxeniEND:vCard</entity>
  <date>
    <dateTime>2009-02-17</dateTime>
  </date>
</contribute>
</lifeCycle>
<metaMetadata>
  <identifier>
    <catalog>AOR</catalog>
    <entry>d6a13306-fd37-11dd-8da8-3bcb55ee78d9</entry>
  </identifier>
  <contribute>
    <role>
      <source>LOMv1.0</source>
      <value>creator</value>
    </role>
    <entity>BEGIN:vCardArapi;PolyxeniEND:vCard</entity>
    <date>
      <dateTime>2009-02-17</dateTime>
    </date>
  </contribute>
  <metadataSchema>LOMv1.0</metadataSchema>
  <language>en</language>
</metaMetadata>
<technical>
  <format>text/x-imsqti-test-xml</format>
  <size>0</size>
  <location>LOGOS AO repository</location>
  <otherPlatformRequirements>
    <string language="en">Put here other requirements</string>
  </otherPlatformRequirements>
</technical>
<educational>
  <learningResourceType>
    <source>LOMv1.0</source>
    <value>questionnaire</value>
  </learningResourceType>
  <difficulty>
    <source>LOMv1.0</source>
    <value>medium</value>
  </difficulty>
  <typicalLearningTime>
    <duration>PT3H30M</duration>
  </typicalLearningTime>
  <language>en</language>
</educational>
<rights>
```

```
<cost>
  <source>LOMv1.0</source>
  <value>no</value>
</cost>
<copyrightAndOtherRestrictions>
  <source>LOMv1.0</source>
  <value>yes</value>
</copyrightAndOtherRestrictions>
<description>
  <string language="en">Some description</string>
</description>
</rights>

<classification>
  <purpose>
    <value>educational level</value>
  </purpose>
  <taxonPath>
    <source>
      <string language="en">Educational level taxonomy</string>
    </source>
    <taxon>
      <entry>
        <string language="en">Further</string>
      </entry>
    </taxon>
  </taxonPath>
</classification>
<classification>
  <purpose>
    <value>educational objective</value>
  </purpose>
  <taxonPath>
    <source>
      <string language="en">Bloom's taxonomy</string>
    </source>
    <taxon>
      <entry>
        <string language="en">analyze</string>
      </entry>
    </taxon>
  </taxonPath>
  <taxonPath>
    <source>
      <string language="en">icons-stable-061107.xml</string>
    </source>
    <taxon>
      <entry>
        <string language="en">Image of the Virgin Mary#The Virgin
Hodegetria</string>
      </entry>
    </taxon>
  </taxonPath>
  <keyword>
    <string language="en"/>
  </keyword>
  <description>
    <string language="en"/>
  </description>
```



```

        </classification>
    </lom>
</xmlData>
</mdWrap>
</dmdSec>

<fileSec>
    <fileGrp>
        <file ID="id0157bf4c" MIMETYPE="text/x-imsqti-test-xml">
            <FLocat LOCTYPE="URN" xlink:href="d6a13306-fd37-11dd-8da8-
3bcb55ee78d9"/>
        </file>
    </fileGrp>
</fileSec>

<structMap>
    <div DMDID="LOM" ID="id0157bf4c" LABEL="Analyze Virgin Hodegetria Image"
TYPE="assessmenttestobject">
        <fptr FILEID="id0157bf4c"/>
    </div>
</structMap>

</mets>

```

An appropriate test can be dynamically constructed by a special service of the personalization component using the same Learning Design structure used to dynamically create the personalized learning experience. This can be done by finding appropriate Assessment Objects to get bound to the Activities of the Learning Design structure with Learning Objectives (to evaluate them) matching the Learning Objectives associated with those Activities in the same way it was done for the selection of appropriate Learning Objects. This procedure will be described in detail in Section 3.4.4.2.

3.4.1.4. Learning Components

Learning Components correspond to learning experiences that utilize the underlying Learning Objects and Assessment Objects. They are hierarchies of activities supported with LOs or AOs and they are described with educational metadata and possibly sequencing and navigation metadata. An example of a Learning Component represented with METS according to the framework presented in this thesis is given in Table 3.12.

Table 3.12 Example of a Learning Component represented with METS

```

<?xml version="1.0" encoding="UTF-8" standalone="no" ?>
<mets xmlns="http://www.loc.gov/METS/" ID="dc6b5d16"
xmlns:LOM="http://ltsc.ieee.org/xsd/LOM"
xmlns:imsss="http://www.imslobal.org/xsd/imsss"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.loc.gov/METS/ mets.xsd
http://ltsc.ieee.org/xsd/LOM lom.xsd http://www.imslobal.org/xsd/imsss
imsss_v1p0.xsd">
    <metsHdr CREATEDATE="2008-03-03T02:03:20" LASTMODDATE="2008-03-
03T02:03:20">

```

```

    <agent ROLE="CREATOR" TYPE="INDIVIDUAL">
      <name>Polyxeni Arapi</name>
      <note>Any additional information regarding the agent's
activities with respect to the METS document.</note>
    </agent>
    <altRecordID ID="altRecordVersion_2"/>
  </metsHdr>
  <dmdSec ID="LOM">
    <mdWrap LABEL="LOM metadata Record" MDTYPE="LOM"
MIMETYPE="text/xml">
      <xmlData>
        <lom xmlns="http://ltsc.ieee.org/xsd/LOM">
          <general>
            <title>
              <string language="en">Bansko-Razlog School of
Art (vM2)</string>
            </title>
            <identifier>
              <catalog>COR</catalog>
              <entry>dc6b5d16-e919-11dc-8295-
779b8520cfd1</entry>
            </identifier>
            <language>en</language>
            <description>
              <string language="en">This training presents one
of the famous school of iconographic art from the region of Bansko and
Razlog.</string>
            </description>
            <structure>
              <source>LOMv1.0</source>
              <value>hierarchical</value>
            </structure>
            <aggregationLevel>
              <source>LOMv1.0</source>
              <value>3</value>
            </aggregationLevel>
          </general>
          <lifeCycle>
            <version>
              <string language="en">1.0</string>
            </version>
            <status>
              <source>LOMv1.0</source>
              <value>draft</value>
            </status>
            <contribute>
              <role>
                <source>LOMv1.0</source>
                <value>author</value>
              </role>
              <entity>BEGIN: vCardPolyxeni ArapiEND:
vCard</entity>
            <date>
              <dateTime>2008-03-03</dateTime>
            </date>
          </contribute>
        </lifeCycle>
        <metaMetadata>
          <identifier>

```

```

<catalog>COR</catalog>
<entry>dc6b5d16-e919-11dc-8295-
779b8520cfd1</entry>
</identifier>
<contribute>
  <role>
    <source>LOMv1.0</source>
    <value>creator</value>
  </role>
  <entity>BEGIN: vCard Logos Middleware END:
vCard</entity>
  <date>
    <dateTime>2008-03-03</dateTime>
  </date>
</contribute>
<metadataSchema>IEEELOM:1.0</metadataSchema>
<language>en</language>
</metaMetadata>
<technical>
  <format>text/html</format>
  <size>1044</size>
  <location>COR:CO_147068763064020</location>
  <installationRemarks>
    <string language="en">none</string>
  </installationRemarks>
  <otherPlatformRequirements>
    <string language="en">Group Work is required for
computer conferencing</string>
  </otherPlatformRequirements>
</technical>
<educational>
  <interactivityType>
    <source>LOMv1.0</source>
    <value>active</value>
  </interactivityType>
  <learningResourceType>
    <source>LOMv1.0</source>
    <value>lecture</value>
  </learningResourceType>
  <interactivityLevel>
    <source>LOMv1.0</source>
    <value>medium</value>
  </interactivityLevel>
  <semanticDensity>
    <source>LOMv1.0</source>
    <value>medium</value>
  </semanticDensity>
  <intendedEndUserRole>
    <source>LOMv1.0</source>
    <value>learner</value>
  </intendedEndUserRole>
  <context>
    <source>LOMv1.0</source>
    <value>training</value>
  </context>
  <typicalAgeRange>
    <string language="en">18-55</string>
  </typicalAgeRange>
  <difficulty>

```

```

        <source>LOMv1.0</source>
        <value>medium</value>
    </difficulty>
    <typicalLearningTime>
        <duration>PT1H30M</duration>
    </typicalLearningTime>
    <language>en</language>
</educational>
<rights>
    <cost>
        <source>LOMv1.0</source>
        <value>no</value>
    </cost>
    <copyrightAndOtherRestrictions>
        <source>LOMv1.0</source>
        <value>no</value>
    </copyrightAndOtherRestrictions>
    <description>
        <string language="en">Contact Logos</string>
    </description>
</rights>
<classification>
    <purpose>
        <value>educational level</value>
    </purpose>
    <taxonPath>
        <source>
            <string language="en">Educational Level
taxonomy</string>
        </source>
        <taxon>
            <entry>
                <string language="en">Further</string>
            </entry>
        </taxon>
    </taxonPath>
</classification>
<classification>
    <purpose>
        <value>educational objective</value>
    </purpose>
    <taxonPath>
        <source>
            <string
language="en">http://somehost/bloomsubset.owl</string>
        </source>
        <taxon>
            <entry>
                <string
language="en">comprehend</string>
            </entry>
        </taxon>
    </taxonPath>
    <taxonPath>
        <source>
            <string language="en">icons-stable-
061107.xml</string>
        </source>
        <taxon>

```

```

<entry>
  <string language="en">Iconographic
School</string>
</entry>
</taxon>
</taxonPath>
</classification>
</lom>
</xmlData>
</mdWrap>
</dmdSec>

<fileSec>
  <fileGrp>
    <file ID="LO0_ref">
      <FLocat LOCTYPE="URN" xlink:href="0cbc61c7-e6ba-11dc-8f32-
df8fa0c9409a"/>
    </file>
    <file ID="LO1_ref">
      <FLocat LOCTYPE="URN" xlink:href="ff31bcd6-e6b9-11dc-8f32-
df8fa0c9409a"/>
    </file>
    <file ID="LO2_ref">
      <FLocat LOCTYPE="URN" xlink:href="164358c8-e6ba-11dc-8f32-
df8fa0c9409a"/>
    </file>
    <file ID="LO3_ref">
      <FLocat LOCTYPE="URN" xlink:href="a22373ca-e6ba-11dc-8f32-
df8fa0c9409a"/>
    </file>
  </fileGrp>
</fileSec>

<structMap>
  <div DMDID="LOM" ID="C0147068763064020" LABEL="Bansko-Razlog School
of Art (vM1)" TYPE="coursewareobject">
    <div ID="ActStr7e45b623-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Introduction" TYPE="activity">
      <div ID="Activity_7e5daaf6-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Introduction to Bansko-Razlog iconographic school" TYPE="activity">
        <fptr FILEID="LO0_ref"/>
      </div>
    </div>
    <div ID="ActStr7e4ce214-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Famous themes painted by iconographers from Bansko-Razlog
iconographic school" TYPE="activity">
      <div ID="Activity_7e94726b-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Famous iconographic scenes painted by iconographers from Bansko-
Razlog iconographic school" TYPE="activity">
        <fptr FILEID="LO1_ref"/>
      </div>
    </div>
    <div ID="ActStr7e83d098-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Comparative presentation of specific themes painted by Bansko-Razlog
iconographic school members and other schools" TYPE="activity">
      <div ID="Activity_7ec40def-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="Saint Nicholas character painted by iconographers from Bansko-Razlog
iconographic school and other famous iconographic schools" TYPE="activity">
        <fptr FILEID="LO2_ref"/>
      </div>
    </div>
  </div>

```

```

        </div>
        <div ID="Activity_7ec8eff0-e7ca-11dc-9fc5-9d9b44c592ef"
LABEL="The Nativity of Christ scene painted by iconographers from Bansko-
Razlog iconographic school and other famous iconographic schools"
TYPE="activity">
            <fptr FILEID="LO3_ref"/>
        </div>
    </div>
</div>
</structMap>
</mets>

```

The structural map (structMap) outlines the hierarchical structure of the learning experience being encoded, consisting of learning activities that exploit learning objects and assessment objects coming from the underlying level. Only leaf div elements can contain references to files (fptr), which through fileSec point to the LOs' and AOs' ids residing in corresponding repositories. The Learning Component is described as a whole with LOM metadata through dmdSec section.

3.4.1.5. Repositories services

According to the framework of this thesis, the specification of the services offered by ASIDE repositories follow the recommendations of IMS Digital Repositories Interoperability specification [IMS DRI, 2003].

The functions that are supported are:

- Search/Expose: The ability to locate an appropriate object. This can include the ability to browse. The Search function defines the searching of metadata for assets “exposed” by repositories. A repository can be searched directly or using an intermediate search engine.
- Gather/Expose: Obtain metadata about objects in other repositories for federated searches and information clearinghouse. The Gather function allows the aggregation of meta-data from repositories for use in subsequent searches. The Gather function may actively request meta-data from a repository (“pull”) or it can subscribe to a service that notifies the Gather component when meta-data in the repository has been added, deleted or changed (“push”).
- Submit/Store: Provide an object (content and metadata) to a repository for storage. Submit places an object into a repository. Store allows a repository to store the object so that it may be retrieved later.
- Request/Deliver: These functions allow a system user to request learning objects or other resources located with the Search function. The Search function returns repository object identifiers as a list of locations or as a method, such as a Digital Object Identifier (DOI), that resolves to one or more locations. The location

returned by Search resolves to a URL that can then be used to Request the object. The protocol used to deliver a requested learning object depends on the object type.

- **Alert/Expose:** These functions provide a method for notifying interested parties of any changes made to content stored in a repository or repository system. Whenever repository has new metadata matching subscribe parameters, it sends an alert message to the subscribers. These functions are not considered in Phase 1 of the DRI specification.

The services implemented for the management of objects in DO, LO, AO and LC repositories are presented in Table 3.13 categorized according to IMS DRI.

Table 3.13 Summarization of DO, LO, AO and LC repositories implemented services according to IMS DRI recommendations

	DO Repository	LO Repository	AO repository	LC repository
Search/ Expose	search_DO	search_LO fuzzy_search_LO	search_AO fuzzy_search_AO	search_LC fuzzy_search_LC
Submit/ Store	checkin_Description checkout_Description get_DescriptionList	create_LO update_LO delete_LO tag_as_final_LO createOffFinal_LO	create_AO update_AO delete_AO tag_as_final_AO createCopyOfFinal_AO	create_LC update_LC delete_LC render_LC createCopyOfFinal_LC
Request/ Deliver	get_DO get_All_DO_of_media	get_LO get_All_DO_in_LO get_LO_summary	get_AO get_AO_summary	get_LC get_All_LO_in_LC get_LC_summary
Alert/ Expose	These functions are not considered in Phase 1 of the DRI specification. However, in Chapter 1 we describe how these services have been implemented in the context of LOGOS project.			

3.4.2. Learner modeling

The parameters described earlier as important to personalization and their relations are normalized within the conceptual model illustrated in Figure 3.10 and could be considered as a part of a Learner Profile, since they describe in some extent a Learner. We will refer to the model of Figure 3.10 as the Learner Model noticing that a Learner Profile may contain more information; we just focus on what is or what is considered as important by us for the dynamic creation of personalized learning experiences.

A *LearnerGoal* is expressed in terms of *LearningObjectives*. A Learner can have many *LearnerGoals*. A *LearnerGoal* has a *status* property (float in [0, 1]) indicating the satisfaction level of the goal (0 represents no satisfaction, 1 fully satisfied). Using this information one can also infer the previous knowledge of the Learner. The Learner can also define a *priority* for each *LearnerGoal*. The Learner can have several types of Preferences: *EducationalLevel* and *LearningStyle*, *Language*, *LearningProvider* (the author or organization making available the learning objects), *LearningPlanner* (the person that develops Learning Designs) and *Technical* preferences.

Each Learning Objective has a priority (defined by Learner if (s)he wants) and a satisfaction status updated by the LMS using for example the score of the Learner in assessments. Either the priority or the status (depending on the preference of the Learner) can be taken into account in personalization in order to construct the learning experience. A learning objective with status > threshold is considered as satisfied and activities associated with this objective will be excluded from the final learning experience.

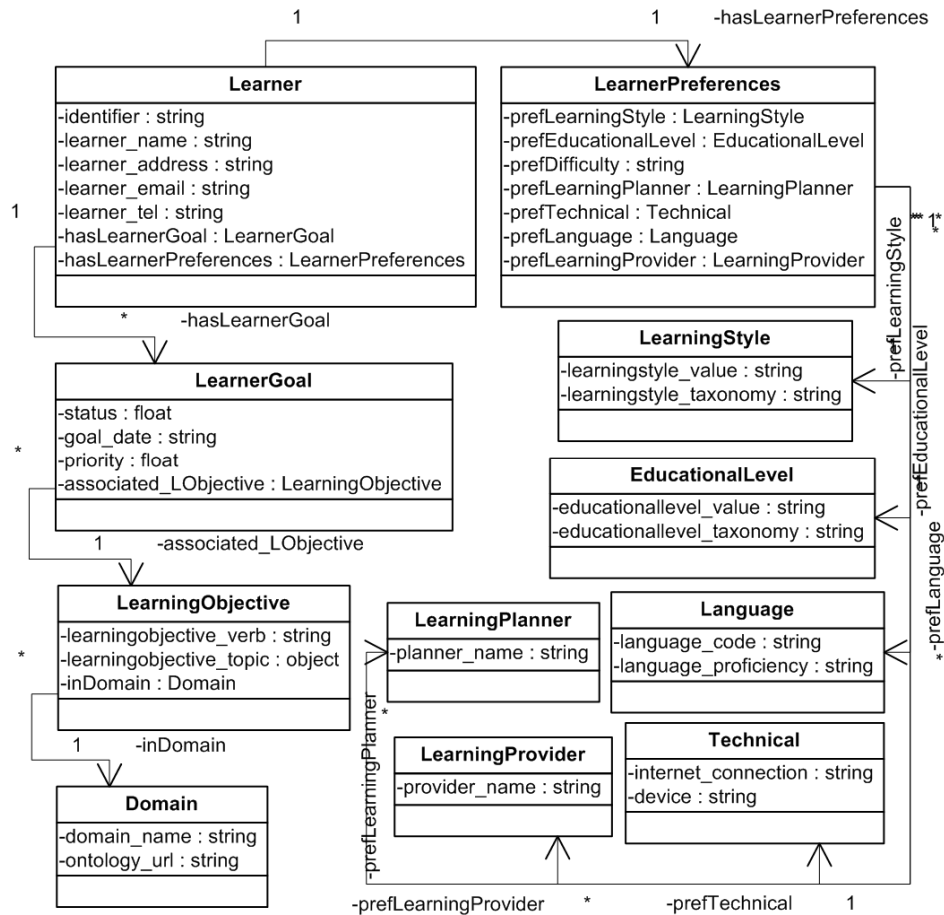


Figure 3.10 Learner Profile classes related with the dynamic creation of personalized learning experiences

Although the Learner may be able to give a priority for a Learning Objective, this is not the case with the status of a Learning Objective indicating how much this Learning Objective has been satisfied in the past (previous knowledge). As we previously mentioned, previous knowledge is an important parameter in personalization processes and there are several methods to identify it. It would not be a reliable method to increase the status of a Learning Objective when a Learning Object associated with this Learning Objective is just attended by the Learner. This is because sometimes the Learner just views and passes the learning content without actually studying it. But even if we assume that the Learner studied the learning content of a Learning Object, this does not always mean that the Learner understood it and that (s)he managed to transform it into knowledge. Moreover, it does not mean that the Learner still remembers what (s)he

learnt. A usual and pretty precise method is using assessments (tests e.t.c.). This is the role of Assessment Objects in this framework presented in the following sections.

As already mentioned, most Learners are unaware of their own learning style and the various approaches. Thus, in most learning style approaches, a corresponding assessment instrument in the form of questionnaire is provided, in order to be able to detect the learning style of a Learner (Table 2.1). This assessment instrument, after its completion by the Learner, will reveal the Learner's dominant learning style(s) according to the current each time learning style approach. However, we should note here that the dominant learning style of the Learner should not be restrictive in the personalization process. It is widely accepted that good learners have developed all learning styles and are able to learn using multiple methods. Hence, although taking account the dominant learning style of a Learner can increase learning efficiency, it would be nice if the Learner could develop other learning styles too. Thus, the Learner should be allowed to "taste" training methods appropriate for different learning styles if (s)he wants to, in order to develop and improve other "learning style skills".

From the previous discussion it should be now clear that not all input parameters in a personalization process restrictively reside in a Learner Profile, but some of them could be given before the initiation of the personalization process, even there is info about them in the Learner Profile (e.g. Learning Style). For example, it makes sense to keep in Learner Profile information about the Learning Objectives in order to be able to know the Learner's knowledge upon specific learning topics.

In Table 3.14 an example of input parameters is given for the initiation of the personalization process represented in an XML document:

Table 3.14 An example of input parameters for the initiation of the personalization process represented in XML

```
<?xml version="1.0" encoding="utf-8"?>
<personalizationParameters xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xsi:noNamespaceSchemaLocation="personalizationParameters.xsd">

  <pedagogicalPreferences>
    <!-- Educational level and difficulty are defined from the Learner for
each Learning Experience request -->
    <educ_diff priority="1">
      <level>Further</level>
      <difficulty>difficult</difficulty>
    </educ_diff>

    <!-- The Learner's dominant Learning Style or preferred Learning Style-->
    <learningStyle>ExampleOriented</learningStyle>

    <!-- All the previous knowledge of the Learner regarding the specific
domain
(Bulgarian Iconography, ontology:icons-stable-061107.xml) -->
    <!-- The targeting Learning Objectives of the Learner are marked as
```

```

selected="true". Those that the generated learning experience should cover.
-->
  <learningObjectives>
    <learningObjective priority="0.7" status="0.3" selected="true">
      <!-- The verb of the learning objective -->
      <verb>comprehend</verb>
      <!-- The domain of the learning objective (Bulgarian Iconography,
ontology:icons-stable-061107.xml) -->
      <source>icons-stable-061107.xml</source>
      <!-- The topic of the learning objective (class#individual) -->
      <topic>Iconographic School#Bansko-Razlog School of Art</topic>
    </learningObjective>

    <learningObjective priority="0.9" status="0.6">
      <verb>describe</verb>
      <source>icons-stable-061107.xml</source>
      <topic>Iconographic School#Bansko-Razlog School of Art</topic>
    </learningObjective>

    <learningObjective priority="0.9" status="0.4" selected="true">
      <verb>compare</verb>
      <source>icons-stable-061107.xml</source>
      <topic>Image of Hierarch#Saint Nicholas</topic>
    </learningObjective>
  </learningObjectives>

  <!--preferred planner (optional element, multiple planners can be
declared): the person who develops Learning Designs-->
  <planner>Polyxeni Arapi</planner>
</pedagogicalPreferences>

<contentPreferences>
  <!-- Preferred Language of the learning experience -->
  <language>en</language>
  <devices>
    <device>PC</device>
    <device>mobile</device>
  </devices>
  <!-- Preferred provider (e.g. author) of LOs (one or more)-->
  <learningProviders>
    <learningProvider>Polyxeni Arapi</learningProvider>
    <learningProvider>Manolis Mylonakis</learningProvider>
  </learningProviders>
</contentPreferences>

  <threshold>0.5</threshold>
</personalizationParameters>

```

It should be noted again here, that the input parameters can be identified in multiple ways and different orders, and this is highly dependent on the implementation of the user interface and generally on the eLearning application strategy. In the last section of this Chapter and in Chapter 5, two different implementation scenarios will be presented.

3.4.3. Instructional modeling - Learning Designs

In all major educational approaches learners perform activities in an environment with resources. In general, a learning design is a way of modeling learning activities and scenarios, as different types of learners prefer different learning approaches depending on their learning styles and other characteristics. Our approach regarding learning designs is fully aligned with the above definition. Specifically, in this framework, Learning Designs are abstract training scenarios that are constructed according to the instructional model presented in Figure 3.11.

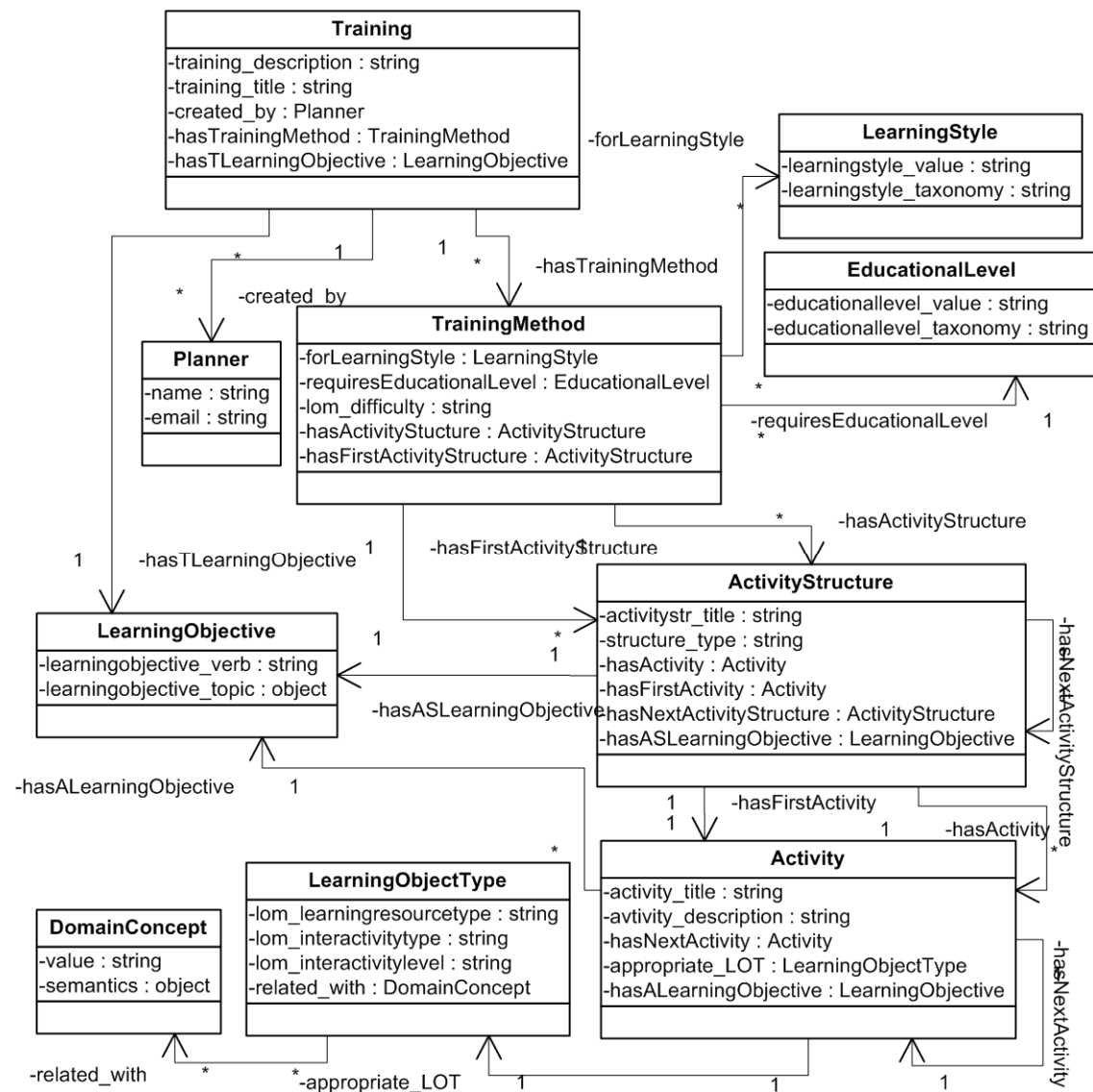


Figure 3.11 The instructional model used in the construction of Learning Designs

In comparison with other approaches, this model has the important characteristic that learning objects are not bound to the training scenarios at design time, as in current eLearning standards and specifications (e.g. IMS Learning Design - IMS LD - and SCORM). Whereas, pedagogy is separated and independent from content achieving this way reusability of Learning Designs or parts of them that can be used from the systems

for the construction of “real” personalized learning experiences, where appropriate learning objects are bound to the learning experience at run-time taking into account the Learner’s needs and preferences. This is possible, since the model gives the opportunity to specify in each Activity the learning objects’ requirements, instead of binding the learning objects themselves. This ontology exploits some elements and ideas from IMS LD and LOM. These preferences do not influence the organization of the learning plan but they are taken into account in the selection of appropriate learning objects.

A *Training* is a collection of *TrainingMethods* that refer to the different ways the same subject can be taught depending on the *LearningStyle*, the *EducationalLevel* of the Learner and the preferred difficulty. There are several categorizations of Learning Styles and Educational Levels, thus these elements are flexible so that being able to point to values of different taxonomies. A *TrainingMethod* consists of a hierarchy of reusable *ActivityStructures* built from reusable Activities. Each *Training*, *ActivityStructure* and Activity has a *LearningObjective*. Each *LearningObjective* is defined using the approach presented earlier. In particular it is composed of: (a) a *learningobjective_verb*, taken from a subset of Bloom's Taxonomy [Bloom and Krathwohl, 1965] and (b) a *learningobjective_topic* that indicates the topic that the Learning Objective is about, referencing a concept or individual of a domain ontology. The *LearningObjectType* is used to describe the desired learning object characteristics without binding specific objects with Activities at design time.

Via the *related_with* property we can further restrict the preferred learning objects according to the *semantics* of their constituent parts (if they are semantically annotated). The value of *semantics* could be a concept or an individual from a domain ontology or even a complex query specifying the semantic requirements that the underlying material of the candidate learning objects should satisfy. The format of the semantics depends on the model, schema or ontology language used to semantically annotate the underlying digital objects that are used in learning objects. In case that conceptual graphs formalism has been used for the annotation of digital objects then this query will be also a conceptual graph expressed in Cogitant XML (COXML) [CoGXML, 2008]. If OWL [OWL 2, 2009] is used for the annotation then, such a query could be expressed in SPARQL [SPARQL, 2008]. The semantic part of MPEG-7 appropriately integrated with domain knowledge from domain ontologies could be also used for powerful annotations of audiovisual material using the methodology described in [Tsinaraki, Polydoros, Christodoulakis, 2004]. In this case MPEG-7 Query Language (MP7QL) [Tsinaraki C. and Christodoulakis, 2007a, 200b] could be used to form such a query.

3.4.3.1. An example of a Learning Design

Let's consider that the taxonomy given in Table 3.15 defines the training subject, which in this case is the Sharable Content Object Reference Model (SCORM).

Table 3.15 A taxonomy describing the SCORM domain

Sharable Content Object Reference Model (SCORM)

- Content Aggregation Model (CAM)
 - Content Model
 - Content Model Component
 - Asset
 - Sharable Content Object (SCO)
 - Content Organization
 - Metadata
 - Content Aggregation Metadata
 - Content Organization Metadata
 - Activity Metadata
 - Sharable Content Object Metadata
 - Asset Metadata
 - Content Packaging
 - Content Package
 - Content Package Component
 - Manifest
 - Manifest Component
 - Metadata
 - Organizations
 - Resources
 - (Sub)Manifest
 - Physical Files
 - Package Interchange File (PIF)
- Run-Time Environment (RTE)
 - Run-Time Environment (RTE) Component
 - Launch
 - Application Programming Interface (API)
 - Data Model

An example of a Learning Design for teaching the basic concepts of SCORM is given in Table 3.16. This Learning Design is represented using XML.

Table 3.16 Example of a Learning Design

```
<learningDesign>
  <metaData>
    <!-- LOM Metadata -->
  </metaData>
  <training id="T1" lobjectiveref="LVT1">
    <title>SCORM</title>
    <description>Training about SCORM</description>

    <trainingMethod id="TM1">
      <learningStyle>
        <source>http://.../learningstyles.owl</source>
      </learningStyle>
    </trainingMethod>
  </training>
</learningDesign>
```

```

        <value>GeneralToSpecific</value>
    </learningStyle>
    <educationalLevel>
        <source>http://.../educationallevels.owl</source>
        <value>Further</value>
    </educationalLevel>
    <difficulty>medium</difficulty>
    <activityStructure id="AS1" lobjectiveref="LVA1" op="AND">
        <title>SCORM Overview</title>
        <activity id="A1" lobjectiveref="LVA1" lotref="LOTA1">
            <title>eLearning Standards Introduction</title>
        </activity>
        <activity id="A2" lobjectiveref="LVA2" lotref="LOTA2">
            <title>Advanced Distributed Learning (ADL)</title>
        </activity>
        <activity id="A3" lobjectiveref="LVA3" lotref="LOTA3">
            <title>What is SCORM?</title>
        </activity>
    </activityStructure>
    <activityStructure id="AS2" lobjectiveref="LVA2" op="AND">
        <title>Content Aggregation Model</title>
        <activity id="A4" lobjectiveref="LVA4" lotref="LOTA4">
            <title>What is the Content Aggregation Model?</title>
        </activity>
        <activity id="A5" lobjectiveref="LVA5" lotref="LOTA5">
            <title>Content Model</title>
        </activity>
        <activityStructure id="AS3" lobjectiveref="LVA3" op="AND">
            <title>Content Model Components</title>
            <activity id="A6" lobjectiveref="LVA6" lotref="LOTA6">
                <title>Assets</title>
            </activity>
            ...
        </activityStructure>
    </activityStructure>
</trainingMethod>
<trainingMethod id="TM2">
    <!--An other TM for other L.Style, Ed.Level or Difficulty -->
</trainingMethod>
</training>

<!--Learning Objectives associated with Training, Activities Structures or
Activities. -->
<learningObjectives>
    <learningObjective id="LVT1">
        <verb>comprehend</verb>
        <topic>
            <!-- The Url of a domain ontology describing the SCORM domain -->

            <source>http://somehost/scorm2004ontology.owl
            </source>
            <value>SCORM</value>
        </topic>
    </learningObjective>
    <learningObjective id="LVA1">
        <verb>describe</verb>
        <topic>
            <source>http://somehost/scorm2004ontology.owl
            </source>

```

```

        <value>SCORM</value>
      </topic>
    </learningObjective>
    ...
  </learningObjectives>

  <!--Desired Learning Objects Characteristics to be connected with Activities
  at run-time-->
  <lots>
    <!-- lot for Activity "Assets" -->
    <lot id="LOTA6">
      <learningResourceType>slide</learningResource-Type>
      <format>text/html</format>
      <interactivityType>active</interactivityType>
      <interactivityLevel>very low</interactivityLevel>
    </lot>
    ...
  </lots>
</learningDesign>

```

3.4.4. Adaptation modeling - Personalization Component

The creation of personalized learning experiences from audiovisual learning objects is done by the Personalization Component that cooperates with a number of other components of the ASIDE architecture. The components that are involved in the creation of personalized learning experiences are presented in Figure 3.12 that illustrates the architecture of the personalization subsystem. This architecture is generic and allows for the dynamic pedagogy-driven creation of personalized learning experiences. In this architecture, pedagogy is clearly separated from content and their binding occurs at run-time depending on the current Learner's educational needs and preferences that affect both the structure of the learning experience (pedagogy) and the selection of appropriate learning content.

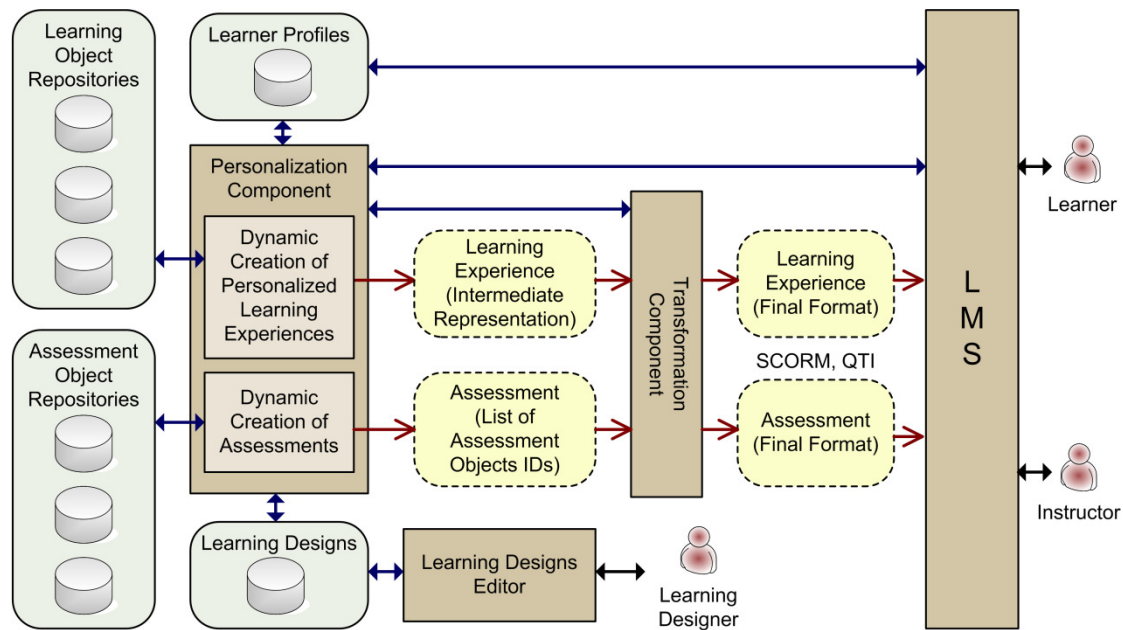


Figure 3.12 Overall architecture for the dynamic construction of pedagogy-driven personalized learning experiences

The main component of this architecture is the **Personalization Component**, which has two roles:

1. The **Dynamic Creation of Personalized Learning Experiences**, taking into account the individual Learner's needs and preferences described in Learner Profile, and
2. The **Dynamic Creation of Assessments** in order to "measure" the previous knowledge of the Learner and update his/her Learner Profile

In the **Dynamic Creation of Personalized Learning Experiences**, the Personalization Component takes into account the **Learner Profile** and tries to find an appropriate **Learning Design** that will be thereafter applied to the construction of a personalized learning experience. Then, based on the selected Learning Design, which is essentially a hierarchy of activities associated with learning objectives, the Personalization Component searches for appropriate learning objects in the **Learning Object Repositories** to get bound to each activity, using information from the Learner's Profile and builds an intermediate representation of the learning experience (**Learning Experience Intermediate Representation**). Thereafter, the **Transformation Component** creates an appropriate format of the learning experience (e.g. a SCORM package) from this intermediate representation. Finally, an appropriate **Learning Management System (LMS)** (e.g. a SCORM compliant LMS) is used to deliver the constructed personalized learning experience to the Learner. It is assumed that this LMS is also able to track Learner's progress in order to keep the Learner Profile up to date. A tool, called

Learning Designs Editor is used for the creation of Learning Designs that are stored thereafter in an appropriate repository.

In the **Dynamic Creation of Assessments**, the Personalization Component follows a similar procedure to those of the dynamic creation of personalized learning experiences. The goal of the dynamic creation of assessment objects in the personalization process is to evaluate the knowledge of the Learner in the specific educational subdomain defined by a **Learning Design** (as a hierarchy of learning objectives) in order to update his/her profile and perform a more effective personalization. Based on the Learning Design that has been selected according to the Learner's goals and which essentially defines the scope of the personalization, the Personalization Component searches for appropriate assessment objects in the **Assessment Object Repositories** to get bound to each activity. While Learning Objects are built to fulfill specific learning objectives, Assessment Objects are used to evaluate learning objectives. This Learning Design could be the one selected during the procedure of the dynamic creation of personalized learning experiences or can be selected independently any time according to the **Learner Profile**. The result of the dynamic creation of assessment will be a list with the appropriate assessment objects identifiers. These will be presented thereafter one by one to the Learner by a **Learning Management System** to complete them in order to evaluate his/her knowledge on the related concepts and finally update his/her profile.

In order for the Personalization Component to be able to retrieve learning objects and assessment objects from learning object/assessment object repositories these should be described in a consistent way (as described in Section 3.4.1). For that, the representation of these objects is based on the interoperability framework that has been already presented that exploits the METS digital library standard in order to describe them in a flexible and interoperable manner. Moreover, several pedagogical properties should exist in their LOM metadata allowing adaptive selection of them at run-time according to the learning style of the Learner and his/her other needs and preferences.

In the following sections we describe in detail each component of the personalization architecture.

3.4.4.1. Dynamic creation of pedagogy-driven personalized learning experiences

The Personalization Component takes into account the knowledge provided by the Learning Designs and the Learner Profiles and constructs personalized learning experiences that are delivered next to eLearning applications in an appropriate form (e.g. as a SCORM package). Specifically, the goal is to find an appropriate Training Method of a Learning Design that will be used thereafter to construct a learning experience adapted to the Learner's needs. As already mentioned, learning objects are bound to the learning scenario at run-time.

The procedure of constructing an adaptive learning experience is illustrated in Figure 3.13. In each step several parameters of the Learner Profile (given in brackets in Figure 3.13) are taken into account:

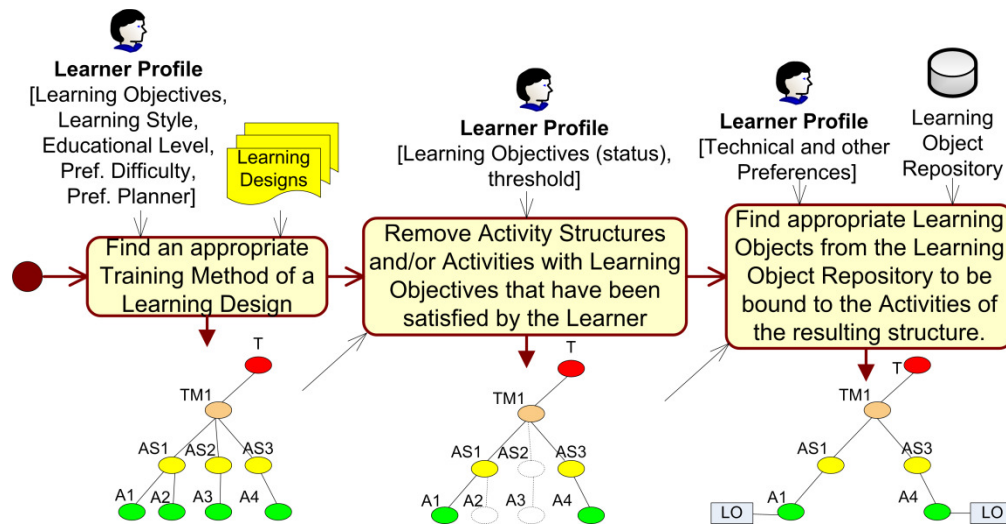


Figure 3.13 The procedure of dynamic construction of personalized learning experiences

Step 1

At the beginning, the component tries to find an appropriate Training Method of a Learning Design taking into account the Learner's Goals, Learning Style, Educational Level, preferred Difficulty, and preferred Planner. Table 3.17 shows the elements that are matched between the Learner Profile and the candidate Learning Designs during this process.

Table 3.17 Matching between Learner Profile properties and Learning Designs properties

Learner Profile	Learning Designs
Learner/hasLearnerGoal/LearnerGoal/associated_LObjective/LearningObjective[@verb,@topic]	Training/hasTLObjective/LearningObjective[@verb,@topic]
	Training/hasTrainingMethod/TrainingMethod/hasActivityStructure/ActivityStructure/hasASLearningObjective/LearningObjective[@verb,@topic]
	Training/hasTrainingMethod/TrainingMethod/hasActivityStructure/ActivityStructure/hasActivity/Activity/hasALEarningObjective/LearningObjective[@verb,@topic]
Learner/hasLearnerPreferences/LearnerPreferences/prefLearningStyle/LearningStyle[@learningstyle_taxonomy, @learningstyle_value]	Training/hasTrainingMethod/TrainingMethod/forLearningStyle/LearningStyle[@learningstyle_taxonomy, @learningstyle_value]
Learner/hasLearnerPreferences/LearnerPreferences/prefEducationalLevel/EducationalLevelI[@educationallevel_taxonomy, @educationallevel_value]	Training/hasTrainingMethod/TrainingMethod/requiresEducationalLevel/EducationalLevelI[@educationallevel_taxonomy, @educationallevel_value]
Learner/hasLearnerPreferences/LearnerPreferences/@prefDifficulty	Training/hasTrainingMethod/TrainingMethod[@lom_difficulty]
Learner/hasLearnerPreferences/LearnerPreferences/prefLearningPlanner/LearningPlanner	Training/created_by/Planner[@name,@string]

anner[@planner_name]	
----------------------	--

To do so, the existing Training Methods are ranked using the following formula:

$$w_{TM} = a_{LV} \cdot w_{LV} + a_{LS} \cdot w_{LS} + a_{EL} \cdot w_{EL} + a_D \cdot w_D + a_P \cdot w_P$$

Where: $a_{LV} + a_{LS} + a_{EL} + a_D + a_P = 1$

w_{LV} is a weight in [0,1] representing the degree of satisfaction of Learner's Learning Goals from the Learning Objectives associated (indirectly) with the Training Method. That includes the Learning Objective of its parent Training and the Learning Objectives of its Activity Structures and Activities. This weight is computed as follows:

$$w_{LV} = \frac{\sum_{i=1}^n p_i}{n}, \text{ where } p_1, \dots, p_n \text{ are the priorities of the Learning Goals of the Learner}$$

taking into account only those Learning Goals that correspond to Learning Objectives associated with the Training Method.

w_{LS} is 1 if the Training Method's associated Learning Style matches the Learning Style of the Learner and 0 otherwise. Note that depending on the taxonomy of Learning Styles used, we may have similarities between different Learning Styles. In that case, these similarities can be used to compute this weight.

w_{EL} is a weight in [0,1] representing the degree of similarity between the Educational Level of the Training Method and the Learner's preferred Educational Level. To compute this weight, we assume that the different (ordered) textual values of Educational Level are mapped to [0,1] so that higher Educational Level values are closer to 1. The simplest way to achieve this is to map the lowest Educational Level to 0, map the higher Educational Level to 1 and all intermediate values are mapped uniformly in [0,1] with distance between two successive values equal to $1/(n-1)$ where n is the total distinct Educational Level values. Then, w_{EL} can be computed as follows:

$$w_{EL} = 1 - (|e_P - e_{TM}| + e_P \cdot f(e_{TM} - e_P))$$

where e_P is the preferred Educational Level of the Learner (the one stored in his profile), e_{TM} is the Educational Level of the Training Method, and f is a function

defined as
$$f(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases}$$

The above formula is based on the assumption that Educational Level levels that are lower than the preferred Educational Level of the Learner are more appropriate than higher Educational Level levels.

w_D is a weight in $[0,1]$ representing the degree of similarity between the Difficulty of the Training Method and the Learner's preferred Difficulty. To compute this weight, we assume that the different (ordered) textual values of Difficulty are mapped to $[0,1]$ so that higher Difficulty values are closer to 1. The simplest way to achieve this is to map the lowest difficulty to 0, map the higher difficulty to 1 and all intermediate values are mapped uniformly in $[0,1]$ with distance between two successive values equal to $1/(n-1)$ where n is the total distinct Difficulty values. Then, w_D can be computed as follows:

$$w_D = 1 - (|d_P - d_{TM}| + d_P \cdot f(d_{TM} - d_P))$$

where d_P is the preferred Difficulty of the Learner (the one stored in his profile), d_{TM} is the difficulty of the Training Method, and f is a function defined as $f(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases}$.

The above formula is based on the assumption that Difficulty levels that are lower than the preferred Difficulty of the Learner are more appropriate than higher Difficulty levels.

w_P is 1 if the Training Method's Planner (i.e. the one associated with its parent Training) is one of the Learner's preferred Planners and 0 otherwise.

Step 2

When an appropriate Training Method is found its structure is further refined, by removing from it Activity Structures and Activities with Learning Objectives that have been satisfied by the Learner (Learning Objectives with satisfaction value greater than a threshold value t are considered as satisfied).

Step 3

Finally, appropriate learning objects are retrieved and bound to each node (Activity) of this structure constructing the learning experience.

Table 3.18 Matching between Learning Design Properties and Learning Objects Metadata

Learning Design	Learning Objects Metadata
Training/TrainingMethod/ActivityStructure/Activity/Learning ObjectType/lom_learning_ResourceType	lom/educational/learning_ResourceType
Training/TrainingMethod/ActivityStructure/Activity/Learning ObjectType/lom_interactivityType	lom/educational/interactivityType
Training/TrainingMethod/ActivityStructure/Activity/Learning ObjectType/lom_interactivityLevel	lom/educational/interactivityLevel
Training/TrainingMethod/ActivityStructure/Activity/Learning ObjectType/lom_semanticDensity	lom/educational/semanticDensity
Training/TrainingMethod/ActivityStructure/Activity/Learning Objective/verb	lom/classification/taxonpath[1]/taxon/ent ry/string

Training/TrainingMethod/ActivityStructure/Activity/Learning Objective/topic	lom/classification/taxonpath[2]/taxon/entry/string
Training/TrainingMethod/difficulty	lom/educational/difficulty
Training/TrainingMethod/EducationalLevel	lom/classification/taxonpath[1]/taxon/entry/string

In order for a learning object to be appropriate for an activity it must at least satisfy its Learning Objective which consists of a verb and a topic. Complementary, other parameters are taken into account that concern other properties of the learning object as previously mentioned and presented again in Table 3.5 and Table 3.18, as well as parameters that are related with the context of use of those learning objects (e.g. technical) that come from the Learners' preferences. From the above we can extract a mathematical relation from which the rank of each learning object is computed in terms of an activity, so that the learning object with the highest rank will be finally bound to the activity as the most appropriate one.

For this reason we use Fuzzy Filters. Fuzzy LOM filters have the same structure as Boolean LOM filters. The difference is that the nodes of Fuzzy LOM filters have an additional weight that specifies the relative importance of the node in the set of nodes of its parent. The root node of the filter does not have a weight (it is useless because the root node does not have a parent node).

The evaluation formulae for fuzzy LOM filters are based on the extended Boolean model [Lee et al., 1993]. To describe the evaluation of queries in this model we assume that F is an evaluation function $F : Q \times O \rightarrow [0,1]$ that gives a value from $[0,1]$ to any valid query $q \in Q$ for each Learning Object $o \in O$. This function is defined recursively as follows:

$$\begin{aligned}
 - \quad F(\langle t_1, w_1 \rangle OR \dots OR \langle t_N, w_N \rangle, o) &= \left(\frac{\sum_{i=1}^N F(t_i, o)^p \cdot w_i^p}{\sum_{i=1}^N w_i^p} \right)^{1/p} \\
 - \quad F(\langle t_1, w_1 \rangle AND \dots AND \langle t_N, w_N \rangle, o) &= 1 - \left(\frac{\sum_{i=1}^N (1 - F(t_i, o))^p \cdot w_i^p}{\sum_{i=1}^N w_i^p} \right)^{1/p} \\
 - \quad F(NOT \, t, o) &= 1 - F(t, o) \\
 - \quad F(\langle condition_on_LOM_element \rangle, o) &= \begin{cases} 1, & \text{if the condition is true for } o \\ 0, & \text{otherwise} \end{cases}
 \end{aligned}$$

An example of the fuzzy filter that is used for the retrieval of appropriate learning objects for an activity is given in Figure 3.14. The only difference from the graphical

representation of a Boolean LOM filter is the incorporation of the weight in each UTerm, LTerm and Atom node):

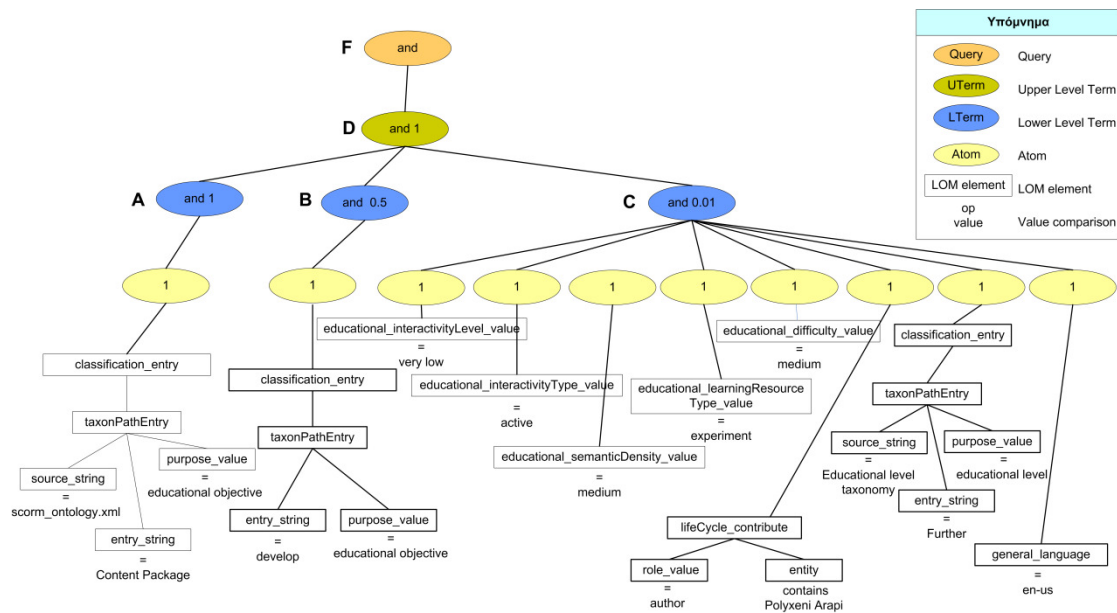


Figure 3.14 Example of fuzzy filter used for the retrieval of appropriate learning objects for an activity

The weights on the LTerm nodes have been appropriately selected in order to retrieve only learning objects that at least satisfy the Learning Objective of the current activity. This has been decided as follows:

Assuming that:

a=topic,

b=verb, and

c=other LO properties

we want:

$$\frac{b}{a+b+c} > \frac{c}{a+b+c} \Leftrightarrow b > c$$

$$\frac{a}{a+b+c} > \frac{b+c}{a+b+c} \Leftrightarrow a > b+c$$

$$\frac{a+b}{a+b+c} > \frac{a+c}{a+b+c} \Leftrightarrow b > c$$

In Figure 3.15 the areas defined by the above relations are presented. We want those areas to be distinct so that there are no overlaps among them. Depending on the area in what the weight of a Learning Object resides, we can conclude which of the above

parameters are satisfied. The minimum requirement that a Learning Object should satisfy in order to be a candidate for an activity is to have a weight that resides in the area defined by the dashed line in Figure 3.15, which in this case means that it satisfies at least the current activity's Learning Objective.

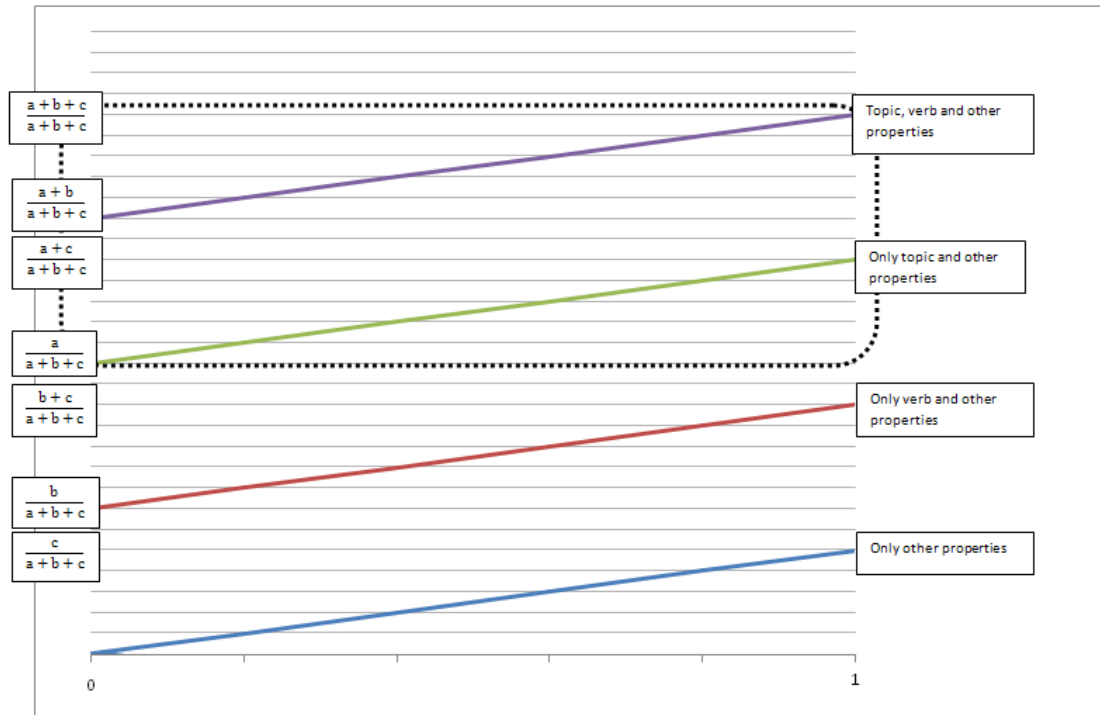


Figure 3.15 Categorization of learning objects (LO ids in the horizontal axis) depending on their weight (vertical axis) as candidates to get bound to an activity or not

A value assignment that satisfies the above mathematic relations is $a=1$, $b=0.5$ and $c=0.01$. So, in order for a LO to be a candidate for an activity it should have a weight

$$w \geq \frac{a+b}{a+b+c} = 0.993$$

meaning that it should at least satisfy the activity's Learning Objective.

Let us assume that a LO o1 has the following characteristics that appropriately reside in its LOM metadata:

- learningResourceType=problem statement
- interactivityType=active
- interactivityLevel=low
- semanticDensity=very high
- Learning Objective: develop Content Package
- difficulty=medium
- Educational Level= Higher Education
- language=en-us

To evaluate the filter f1 of Figure 3.14 for this learning object we do the following:

- $F(<\text{classification_entry}>) = 1$ since
 - $F(<\text{taxonPathEntry}>) = 1$ since
 - $F(<\text{source_string}, =, \text{scorm_ontology.xml}>, o1) = 1$
 - $F(<\text{entry_string}, =, \text{Content Package}>, o1) = 1$
 - $F(<\text{purpose_value}, =, \text{educational objective}>, o1) = 1$
- $F(<\text{classification_entry}>) = 1$ since
 - $F(<\text{taxonPathEntry}>) = 1$ since
 - $F(<\text{entry_string}, =, \text{develop}>, o1) = 1$
 - $F(<\text{purpose_value}, =, \text{educational objective}>, o1) = 1$
- $F(<\text{educational_interactivityLevel}, =, \text{low}>, o1) = 0$
- $F(<\text{educational_interactivityType}, =, \text{active}>, o1) = 1$
- $F(<\text{educational_semanticDensity}, =, \text{very high}>, o1) = 0$
- $F(<\text{educational_learningResourceType}, =, \text{problem statement}>, o1) = 0$
- $F(<\text{educational_difficulty}, =, \text{medium}>, o1) = 1$
- $F(<\text{lifeCycle_contribute}>) = 1$ since
 - $F(<\text{lifeCycle_contribute_role_value}, =, \text{author}>, o1) = 1$
 - $F(<\text{lifeCycle_contribute_entry}, =, \text{Polyxeni Arapi}>, o1) = 1$
- $F(<\text{classification_entry}>) = 0$ since
 - $F(<\text{taxonPathEntry}>) = 0$ since
 - $F(<\text{source_string}, =, \text{Educational Level Taxonomy}>, o1) = 1$
 - $F(<\text{entry_string}, =, \text{Higher Education}>, o1) = 0$
 - $F(<\text{purpose_value}, =, \text{educational level}>, o1) = 1$
- $F(<\text{general_language}, =, \text{en-us}>, o1) = 1$

Then, the following equations hold:

$$A = 1 - \left(\frac{(1-1)^p \cdot 1^p}{1^p} \right)^{\frac{1}{p}} = 1$$

$$B = 1 - \left(\frac{(1-1)^p \cdot 1^p}{1^p} \right)^{\frac{1}{p}} = 1$$

$$C = 1 - \left(\frac{4 \cdot (1-0)^p \cdot 1^p + 4 \cdot (1-1)^p \cdot 1^p}{1^p + 1^p + 1^p + 1^p + 1^p + 1^p + 1^p + 1^p} \right)^{\frac{1}{p}} = 1 - \left(\frac{4}{8} \right)^{\frac{1}{p}} = 1 - 0.5^{\frac{1}{p}}$$

$$D = 1 - \left(\frac{(1-A)^p \cdot 1^p + (1-B)^p \cdot 0.5^p + (1-C)^p \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}} = 1 - \left(\frac{0 + 0 + (1-C)^p \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}} =$$

$$= 1 - \left(\frac{0 + 0 + \left(1 - 1 + 0.5^{\frac{1}{p}} \right)^p \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}} = 1 - \left(\frac{0.5 \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}}$$

$$F(f1, o1) = 1 - \left(\frac{\left(1 - \left(1 - \left(\frac{0.5 \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}} \right)^p \right)^p \cdot 1^p}{1^p} \right)^{\frac{1}{p}} = 1 - \left(\frac{0.5 \cdot 0.01^p}{1^p + 0.5^p + 0.01^p} \right)^{\frac{1}{p}}$$

For $p=1$ the above formula gives approximately:

$$F(f1, o1) = 0.996688741721854304635761589404$$

Hence, learning object o1 is a candidate that may be bound to the current activity since $F(f1, o1)$ is within the allowed range, and if there is no other object o2 with $F(f1, o2) > F(f1, o1)$, learning object o2 will be bound to the current activity as the most appropriate one.

3.4.4.2. Dynamic creation of Assessment Tests for the evaluation of Learner knowledge

The procedure for the dynamic creation of Assessment Test for the evaluation of Learner's knowledge is similar to this of the dynamic creation of personalized learning experiences:

1. The LMS calls the service for the dynamic construction of Assessments based on the Training Method selected by the Learner.
2. The service for the dynamic construction of Assessments prepares an Assessment (essentially a set of appropriate Assessment Objects – Items or Tests) to evaluate all the learning objectives that are connected with the selected Training Method's structure. Specifically, it is trying to find appropriate Assessment Objects (Assessment Tests Objects or Assessment Item Objects) that will be bound to the Activities of the selected Training Method. The type of the selected Assessment for an Activity depends on how broad (high-level) a learning objective is. For example in order to evaluate a learning objective of the type “comprehend Bulgarian Iconography” a simple question (Assessment Item) would not be adequate. Finally, the service returns to the LMS a simple XML file containing only the sequence of the selected Assessment Objects IDs and a type attribute indicating whether an Assessment ID corresponds to an Assessment Test Object or an Assessment Item Object (see `DynamicAssessmentExample.xml`).

The following Steps (3-5) are repeated for each Assessment Object ID in the sequence given in the XML file:

3. The LMS presents Assessment Object to the Learner.
4. The Learner completes the current Assessment Object and submits his/her answers to the LMS.
5. The LMS evaluates Learner's answer(s) in current Assessment Object and presents the results to the Learner.

3.4.5. Transformation Component

The intermediate format of the learning experience generated as a result of the personalization process described in the previous section is transformed by the Transformation Component to an appropriate format and delivered to the Learner. Figure 3.16 illustrates how the intermediate format is transformed to METS.

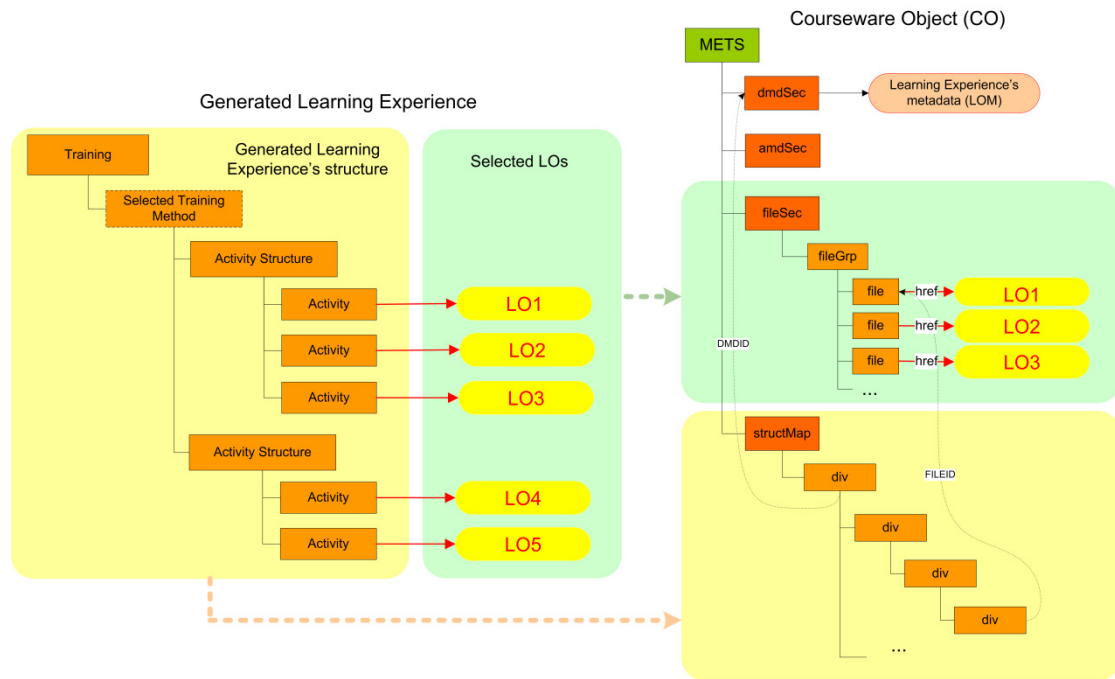


Figure 3.16 Transformation of the intermediate format of the learning experience to the final format (in this case METS)

The METS representation can be further transformed to SCORM in order for the learning experience to be delivered to eLearning applications. In Figure 3.17 and Table 3.19 the mapping between METS and SCORM IMS Manifest is given.

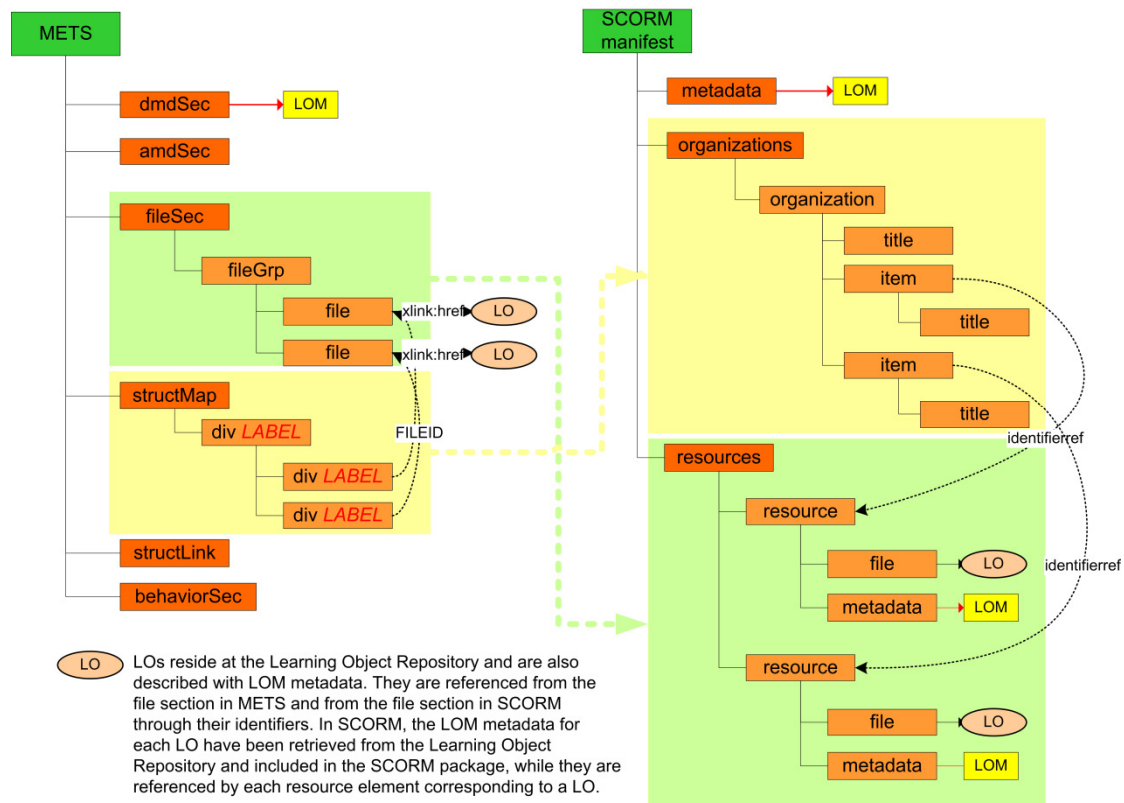


Figure 3.17 Mapping of the METS-based representation of the Learning Component to a SCORM learning experience in order to be delivered to eLearning Applications

Table 3.19 Mapping between METS and SCORM IMS Manifest

METS	SCORM IMS Manifest
structMap	organizations/organization
structMap/@ID	organizations/@default
structMap/@ID	organizations/organization/@identifier
structMap/div/@LABEL	organization/title
structMap/div/@ID	organization/item/@identifier
div/@LABEL	organization/item/title
div/fptr/@FILEID	item/@identifierref
fileSec	resources
fileGrp	resources/resource
fileGrp /@ID	resources/resource/@identifier
file/FLocat/@xlink:href	resources/resource/@href
fileGrp/file	resources/resource/dependency
fileGrp/file/@ID	resources/resource/dependency/@identifierref
fileGrp/file/@ID	resources/resource/@identifier
fileGrp/file/FLocat/href	resources/resource/file/@href
If dmdSec/mdWrap/[@MDTYPE=LOM] dmdSec/mdWrap/xmlData	<adlcp:location>lomfiles/FG1.xml</adlcp:location> Creates an xml document with the LOM metadata for each resource.

The process of transformation does not only include this simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Among others, the type of the underlying physical files is taken into account (from MPEG7 descriptions), as well as the requirements of the delivery channel and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files) and appropriate content transformations are performed. This process will be presented in detail in Chapter 4, where the implementation of the framework in the context of LOGOS Project will be described.

3.5. Summary

In this chapter we presented solutions on how eLearning applications can be supported on top of digital libraries. One aspect of this problem was to support multiple (educational) context views of digital objects with the use of METS. The other aspect was to support the repurposing of digital objects to higher level learning objects and finally learning experiences through appropriate architectures.

We presented the ASIDE architecture, a layered architecture that allows for eLearning Applications to be built on top of (multimedia) digital libraries addressing interoperability problems between them. It has been described how the objects on each layer should be represented using METS and other standards (e.g. LOM, IMS QTI, MPEG7) according to the framework of this thesis, and what should be the common functions provided by the corresponding repositories according to the IMS DRI specification. It has been described how Learners' needs and preferences are identified and represented in a

Learner Model. A rich instructional model able to support the different pedagogical models and instructional theories in the form of abstract training scenarios (Learning Designs) has been presented next. This model accommodates flexible structures in training scenarios composed of learning activities as well as information regarding the individual learning styles, educational level and preferred difficulty of learners. In addition, the pedagogical models are reusable and separated from content, allowing appropriate learning resources according to the Learner profile to be bound to the training scenario at run-time. Finally, the adaptation modeling has been discussed, including the specification of rules and algorithms for the dynamic creation of pedagogy-driven personalized learning experiences to satisfy the needs of different Learners expressed in Learner profiles. These learning experiences are transformed by the Transformation Component to SCORM packages for their delivery to eLearning applications.

Chapter 4. APPLYING THE FRAMEWORK – AN EXAMPLE

4.1. Introduction

In this chapter we give an example of the application of the framework for the dynamic pedagogy-driven creation of personalized learning experiences. The procedure of the environment setup (Author's perspective) is described, in order to support the generation of personalized learning experiences according to this framework, as well as the personalization process as it is initiated and experienced by the Learner (Learner's perspective).

4.2. Setting the environment – The Author's perspective

The preparation of the environment by the Author in order to be able for the system to generate personalized learning experiences includes the following development phases:

1. Development of a domain ontology representing the target learning domain or use of an existing one.
2. Development of learning resources that may include:
 - a. Development of new learning resources (raw assets) or appropriate adaptation of existing resources
 - b. Assembly of self-standing units of learning from collections of content assets and appropriate pedagogical descriptions of them to create learning objects.
 - c. Repurposing of existing learning objects
 - d. Development of Assessment Objects
3. Development of Learning Designs/Training Methods to satisfy different learning needs (e.g. learning style, educational level, difficulty).

Before proceeding with the description of the above development phases and the corresponding results, it is necessary to introduce several instructional strategies to support Honey and Mumford's learning styles, proposed by several authors in the related bibliography, affecting both the construction of learning designs and the creation and description of learning objects.

4.2.1. Instructional strategies to support Honey and Mumford learning styles

Learning styles affect both the construction of the learning plan and the selection of learning objects and this is highly dependent on the taxonomy that is used in a specific environment for the definition of learning styles. For example, for the learning styles defined by Honey and Mumford, Stash [2007] proposes the following instructional strategies:

Activist	<i>Activity-oriented</i> approach: showing content of activity and links to example, theory, exercise
Reflector	<i>Example-oriented</i> approach: showing content of example and links to theory, exercise, activity
Pragmatist	<i>Exercise-oriented</i> approach: showing content of exercise and links to example, theory, activity
Theorist	<i>Theory-oriented</i> approach: showing content of theory and links to example, exercise, activity

Similarly, Papanikolaou et al. [Papanikolaou et al., 2003] propose the following instructional strategies for the learning styles described in the Honey and Mumford model:

- activity-oriented with high interactivity level for activists, who are more motivated by experimentation and challenging tasks;
- example-oriented for reflectors who tend to collect and analyze data before taking action;
- exercise-oriented for pragmatists, as they are keen on trying out ideas, theories and techniques;
- theory-oriented for theorists, giving them the chance to explore and discover concepts in more abstract ways.

According to the proposed approach, all learners are provided with the same knowledge modules | multiple representations of the concepts being studied, such as theory presentations (definitions, descriptions, conclusions), questions introducing or assessing the concept, examples (concrete instantiations of concepts, application examples, analogies), exercises, activities (activities using computer simulation, exploration activities, case studies), definitions in the glossary, etc.. However, the method and order of their presentation is adapted, according to different instructional strategies that focus on different perspectives of the concepts. The various knowledge modules are presented

in different areas of an educational material page, and they are either embedded in the page, or appear as links.

In particular, Papanikolaou et al. [Papanikolaou et al., 2003] propose that an activist starts with an activity and the system then provides him/her with all necessary information. A reflector on the other hand is recommended to start with an example, continue with a brief theory presentation and then try to solve an exercise.

Apart of the above recommendations, the following diagram by Simon Raj that summarizes the important characteristics of Honey and Mumford learning styles could be a helpful guide when constructing instructional strategies to support each of those learning styles (building the instructional plan + building appropriate learning objects).

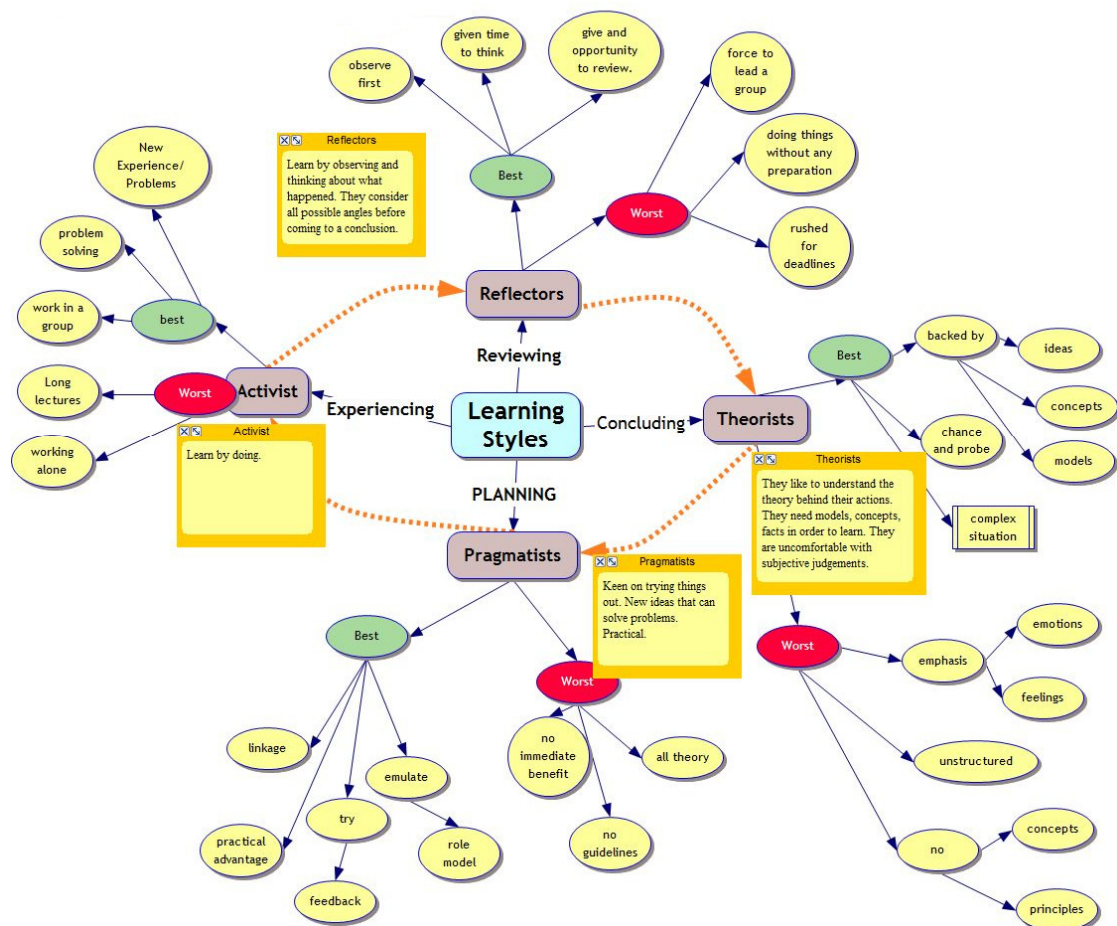


Figure 4.1 Honey and Mumford Learning Styles characteristics⁵

⁵ Retrieved from <http://simonraj.com/blog/?feed=rss2>

4.2.2. Development of a domain ontology representing the target learning domain

The development of a domain ontology or taxonomy representing the target learning domain or use of an existing one is important. The ontology is exploited in the semantic annotation of Digital Objects and the formation of Learning Objectives (in LOs, AOs, LDs) allowing semantic searches on Digital Objects, Learning Objects, and Assessment Objects, and selection of appropriate Learning Objects in personalization process.

For the needs of this example we will use the taxonomy presented in Table 3.15 that describes the SCORM teaching domain.

4.2.3. Development of learning resources

As described in Chapter 3, this process may involve several steps depending each time on the availability and appropriateness of the learning resources in terms of the current context. Usually, this is a multilevel process undertaken by more than one user roles, including the following steps:

- 1) Development of the training material (raw content - assets) or repurposing of existing ones. This process may involve the development of new training material or the adaptation (repurposing) of existing materials in order to fit the needs of the current context. Alternative materials should be developed in order to cover all learning styles of the selected learning style approach (e.g. Honey & Mumford's taxonomy).
- 2) Development of new Learning Objects from assets or repurposing of existing ones. The process of new Learning Objects development includes a) the discovery and arrangement of assets to form a self-standing unit that fulfills a certain Learning Objective, and b) its description with appropriate educational metadata. The process of repurposing includes the discovery of relevant Learning Objects and their adaptation in terms of their content and description to fit to the needs of the current context.
- 3) Development of Assessment Objects. Although Assessments Objects are optional in order for the personalization process to be applied, they are an important means in measuring the previous knowledge of the target Learner, providing him/her with a more appropriate personalized learning experience.

Table 4.1 summarizes the important learning objects metadata elements (LOM) already presented in Section 3.4.1.2 that should be used for the description of learning objects in order to be able to perform personalization according to the framework presented in this thesis.

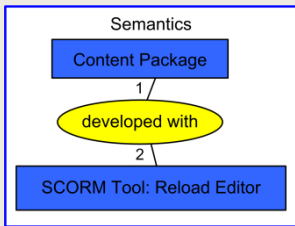
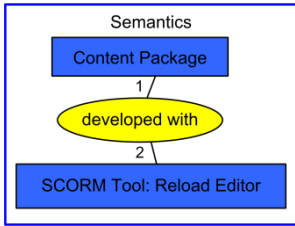
Table 4.1 Important Learning Objects Metadata and corresponding values

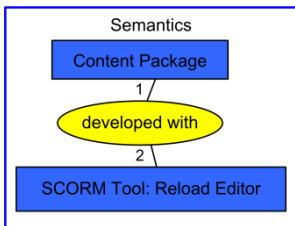
Abbreviation	LOM metadata	values
lrT	Learning Resource Type	See Table 3.6
iT	Interactivity Type	active, expositive, mixed
iL	Interactivity Level	very low, low, medium, high, very high
sD	Semantic Density	very low, low, medium, high, very high
lobv	Learning Objective (represented in classification element)	Verb (Bloom's Taxonomy) + Topic (Domain Ontology)
diff	Difficulty	very easy, easy, medium, difficult, very difficult
el	Educational Level	Primary, Middle, Secondary, Further, Higher Education
auth	Author (contribute element)	

The learning objects that have been developed for the needs of this example are presented in Table 4.2. A number of learning objects with the same learning objective have been developed in order to support the different learning styles. The “Underlying DO Annotation” field indicates that the learning object includes at least one digital object that is annotated as presented. Beyond the important metadata presented earlier, this information is also used when learning object are filtered by the personalization component to match the requirements of activities in a Learning Design (via the `related_with` property). Normally, all learning objects contain digital objects which contain annotations, but for simplicity in Table 2.1 we give only the annotations that will match the needs of this example in the personalization process.

Table 4.2 Learning Objects

LO id	LO Title	LOM metadata	Underlying DO Annotation
drt-s121-012	SCORM definition	lrT: narrative text iT: active iL: medium sD: high lobv: define SCORM diff: medium el: Higher Education	
afc-g311-021	Learning SCORM Components by playing	lrT: simulation iT: active iL: high sD: high lobv: describe SCORM Component diff: medium el: Higher Education	
ffc-g511-425	SCORM Content Packaging	lrT: narrative text iT: active iL: medium sD: very high lobv: define Content Package diff: medium el: Higher Education	

kdc-f413-034	Packaging courses with SCORM	IRT: problem statement iT: active iL: low sD: very high lobv: develop Content Package diff: medium el: Higher Education	 <pre> graph TD CP[Content Package] -- 1 --> D([developed with]) D -- 2 --> RTE[SCORM Tool: Reload Editor] </pre>
hdc-d351-983	SCORM definition	IRT: narrative text iT: expositive iL: medium sD: low lobv: define SCORM diff: medium el: Higher Education	
mld-j311-927	The SCORM parts	IRT: narrative text iT: expositive iL: medium sD: low lobv: describe SCORM Component diff: medium el: Higher Education	
gkc-n311-439	SCORM content packages	IRT: narrative text iT: expositive iL: medium sD: low lobv: define Content Package diff: medium el: Higher Education	
wrc-v715-422	Developing SCORM Content Packages with RELOAD Editor Tutorial	IRT: simulation iT: expositive iL: very low sD: very low lobv: develop Content Package diff: medium el: Higher Education	 <pre> graph TD CP[Content Package] -- 1 --> D([developed with]) D -- 2 --> RTE[SCORM Tool: Reload Editor] </pre>
sgd-r514-026	The SCORM eLearning interoperability standard	IRT: narrative text iT: expositive iL: very low sD: very low lobv: define SCORM diff: medium el: Higher Education	
dhv-t315-201	The SCORM Components	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe SCORM Component diff: medium el: Higher Education	
mbc-t401-904	The SCORM Content Model	IRT: narrative text	

		iT: expositive iL: very low sD: very low lobv: describe Content Model diff: medium el: Higher Education	
kgk-n578-091	Content Packaging with SCORM	IRT: narrative text iT: expositive iL: very low sD: very low lobv: define Content Packaging diff: medium el: Higher Education	
tgh-b573-444	SCORM	IRT: narrative text iT: expositive iL: medium sD: medium lobv: define SCORM diff: medium el: Higher Education	
jkg-c511-906	Inside a SCORM Content Package	IRT: narrative text iT: expositive iL: medium sD: medium lobv: define Content Package diff: medium el: Higher Education	
xds-x491-579	SCORM Content Packages development with RELOAD Editor Walkthrough	IRT: experiment iT: active iL: very low sD: medium lobv: develop Content Package diff: medium el: Higher Education	

Similarly, the Assessment Objects that have been developed for the needs of this example are presented in Table 2.1. The important metadata for Assessments are the learningResourceType (=exercise for Assessment Items, =questionnaire for Assessment Tests), the Learning Objective (expressed via classification element), the difficulty and the educational level. We see that Assessment Items (simple questions) within an Assessment Test may have different weights, as in the case of Assessment Test with id xds-e411-897. If the Learner gives a correct answer to the questions hft-r456-242 ($w = 0.40$) and qvc-r331-921 ($w = 0.40$) but a wrong answer to qvc-r331-921 ($w = 0.40$), then the overall score will be 0.80 and this will be also the satisfaction of the overall Learning Objective associated with Assessment Test, while the satisfaction of the Learning Objectives associated with its Assessment Items will be 0.40, 0.40 and 0.0 respectively. The values of these objectives in the Learner profile will be updated accordingly.

Table 4.3 Assessment Objects

AO id	AO Title	Questions (Assessment Items) included and their weight w in test score	Important LOM metadata
grc-m341-982	What is SCORM?	N/A	IRT: exercise lobv: define SCORM diff: medium el: Higher Education
lvc-e353-943	Which from the following are SCORM Components?	N/A	IRT: exercise lobv: list SCORM diff: medium el: Higher Education
hft-r456-242	What is the SCORM Content Aggregation Model?	N/A	IRT: exercise lobv: describe Content Aggregation Model diff: medium el: Higher Education
qvc-r331-921	What is the SCORM Run-Time Environment?	N/A	IRT: exercise lobv: describe Run-Time Environment diff: medium el: Higher Education
xds-e411-897	Test on SCORM Components	lvc-e353-943 (w = 0.20) hft-r456-242 (w = 0.40) qvc-r331-921 (w = 0.40)	IRT: questionnaire lobv: describe SCORM Component diff: medium el: Higher Education
qre-v213-082	What is a SCORM Content Package?	N/A	IRT: exercise lobv: define Content Package diff: medium el: Higher Education
uec-w311-123	What are the parts of a SCORM Content Package?	N/A	IRT: exercise lobv: list Content Package diff: medium el: Higher Education
mlk-e351-148	What is a Package Interchange File (PIF)?	N/A	IRT: exercise lobv: define Package Interchange File diff: medium el: Higher Education
bnm-m310-920	Test on Content Packaging	qre-v213-082 (w = 0.40) uec-w311-123 (w = 0.40) mlk-e351-148 (w = 0.20)	IRT: questionnaire lobv: describe Content Packaging diff: medium el: Higher Education

4.2.4. Development of Learning Designs/Training Methods

In the following sections the development of Learning Designs is described. In order to be able for the personalization system to generate personalized learning experiences for all Honey and Mumford's learning styles there must be training methods in Learning Designs supporting all of them.

4.2.4.1. Training Method for Activists (Concrete Experience)

Activists learn best from activities where there are new experiences/problems/opportunities from which to learn. They learn least from, and may react against activities where learning involves a passive role, ie., listening to lectures, monologues, explanations, statements of how things should be done, reading, watching.

Consequently, a Training Method for Activists should:

- not include too much theory. Thus, only definitions of necessary concepts may be appropriate (semantic density: very high).
- include activities corresponding to experiences/problems/opportunities. Thus, problem statements (learning Resource Type: problem statement) in order for the Learner to be able to find the meaning behind concepts by “playing” (active experimentation) are very appropriate.
- not include explanations, statements of how things should be done reading, watching (not expository role).

In Figure 4.2 a sample of a training method for teaching SCORM to Activists is illustrated.

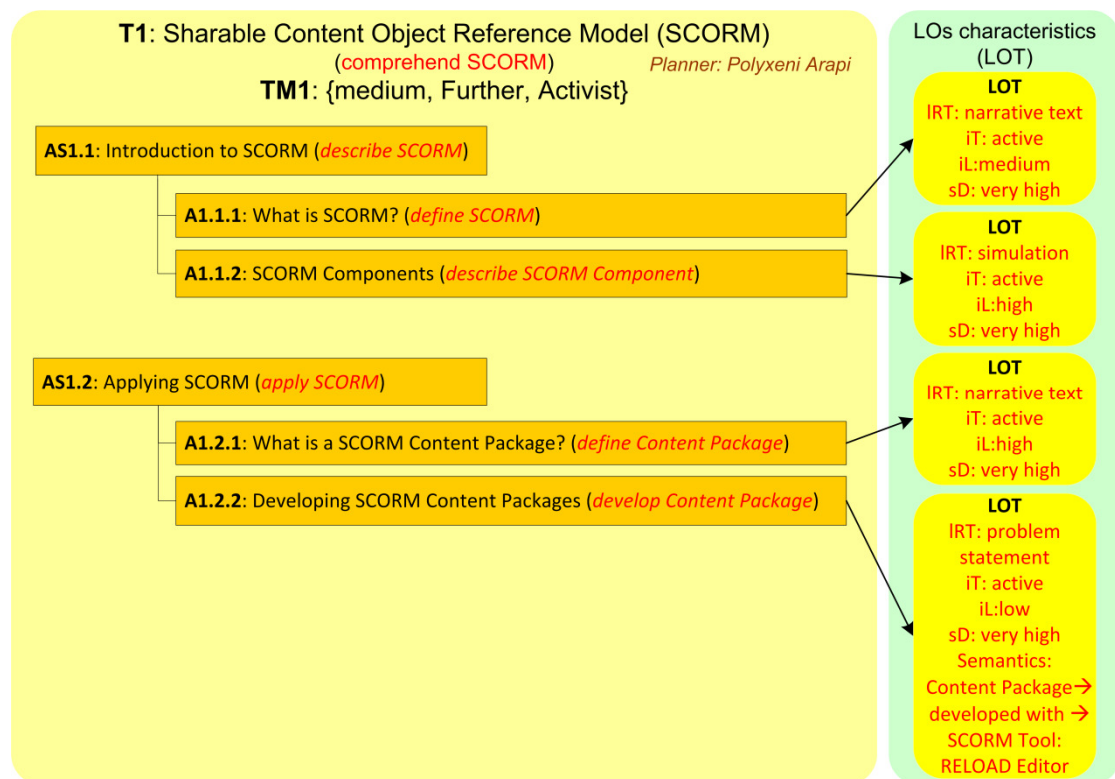


Figure 4.2 Training Method for Activists

4.2.4.2. Training Method for Reflectors (Reflective Observation)

Reflectors learn best from activities where they are allowed or encouraged to watch/think/chew over activities. They are able to stand back from events and listen/observe (i.e., observing a group at work, taking a back seat in a meeting, watching a film or video). They like research and investigation. They learn least from, and may react against activities where they are involved in situations which require action without planning and when they are given insufficient data on which to base a conclusion. They like to read instructions, count pieces and think things through observation but they may react against given cut and dried instructions on how things should be done.

Consequently, a Training Method for Reflectors should:

- include activities where they can watch, observe things e.g. videos or simulations (learning Resource Type: simulation, interactivity type: expositive, interactivity level: low). Thus, video tutorials and manuals are very appropriate for Reflectors.
- not include cut and dried instructions on how things should be done. Thus, walkthroughs are not appropriate for Reflectors.
- include enough theory (sufficient data) but not too much as in the case of a Theorist (semantic density: medium).

In Figure 4.3 a sample of a training method for teaching SCORM to Reflectors is illustrated.

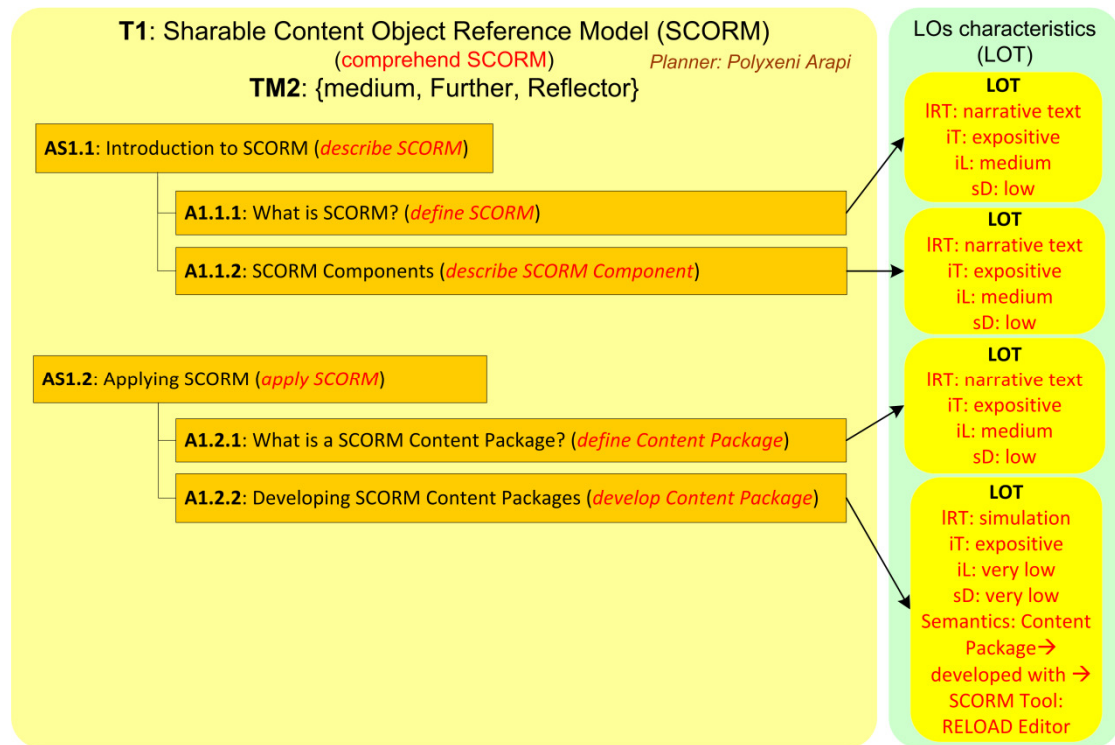


Figure 4.3 Training Method for Reflectors

4.2.4.3. Training Method for Theorists (Abstract Conceptualization)

Theorists learn best from activities where what is being offered is part of a system, model, concept, theory. They like to have the time to explore methodically the associations and interrelationships between ideas, events and situations. They can listen to or read about ideas and concepts that emphasize rationality or logic and are well argued/elegant/watertight. They like structured situations with a clear purpose. They learn least from, and may react against activities where they are faced with a hotchpotch of alternative/contradictory techniques/methods without exploring any in depth (ie., as on a “once over lightly” course). They also learn least from activities where they doubt that the subject matter is methodologically sound. Moreover, they don’t like to study through application of knowledge.

Consequently, a Training Method for Theorists should:

- include activities where what is being offered is part of a system, model, concept, theory. Thus, theory coming from deliverables and manuals, where things are presented in this manner (systems, models, concepts and processes) is very appropriate after some adaptation.
- not include activities where they are forced to study through application of knowledge. Thus, problem statements for active experimentation and walkthroughs are not very appropriate for Theorists.

In Figure 4.4 a sample of a training method for teaching SCORM to Theorists is illustrated.

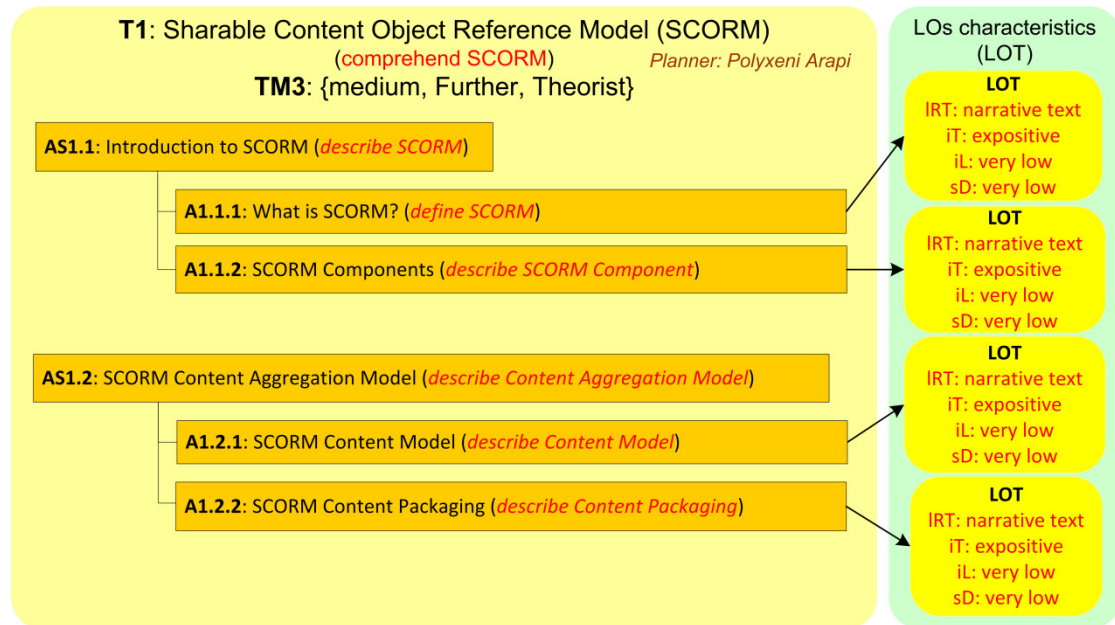


Figure 4.4 Training Method for Theorists

4.2.4.4. Training Method for Pragmatists (Active Experimentation)

Pragmatists learn best from activities where there is an obvious link between the subject matter and the problem or opportunity on the job. They like activities where techniques for doing things with practical advantages are shown. They also learn best from activities where they are exposed to a model they can emulate, i.e., a demonstration from someone with a proven track record, lots of examples/anecdotes, a film showing how it's done. They like techniques currently applicable to their own job. Pragmatists like to work actively on well-defined tasks and learn by trial and error. They like to have immediate opportunities to implement what they have learned. Pragmatists learn least from, and may react against activities where the learning is not related to an immediate need they recognize/they cannot see, an immediate relevance/practical benefit. They learn least when there is no practice or clear guidelines on how to do things.

Consequently, a Training Method for Pragmatists should:

- include activities that allow them to work actively on well-defined tasks and learn by trial and error. So, activities including experiments and Walkthroughs are appropriate.
- include activities where techniques for doing things with practical advantages are shown (demonstrations, examples). Thus, Video Tutorials are very appropriate in this case.

In Figure 4.5 a sample of a training method for teaching SCORM to Pragmatists is illustrated.

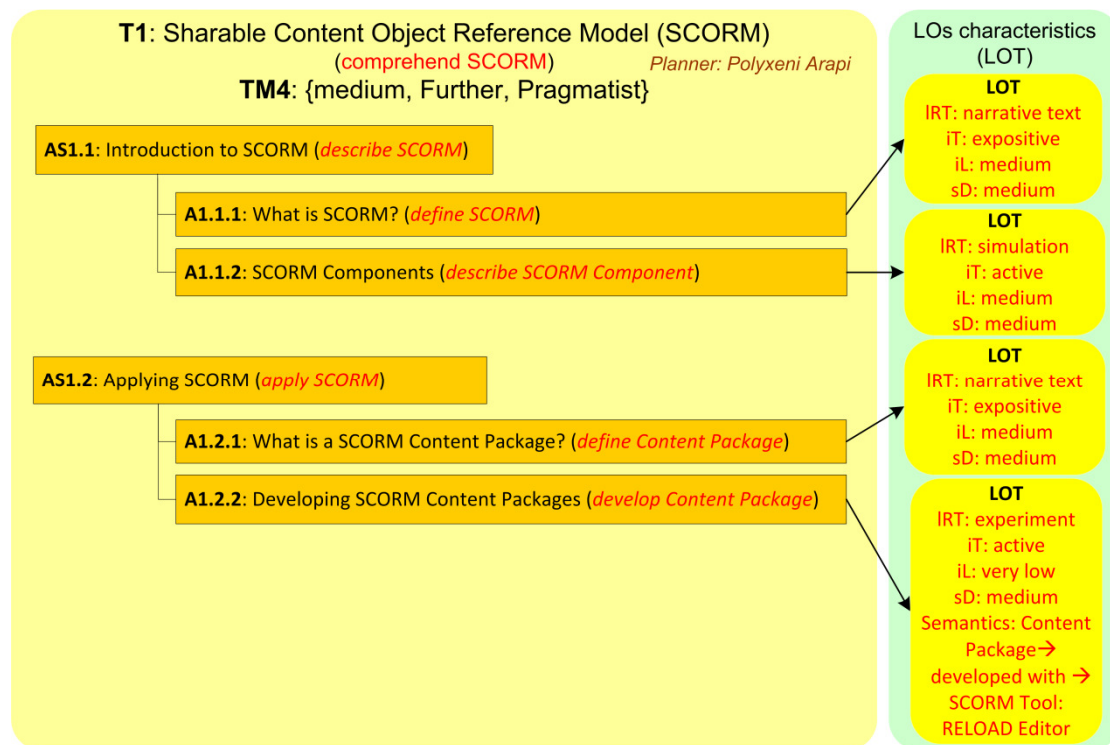


Figure 4.5 Training Method for Pragmatists

4.3. The personalization process – The Learner's perspective

In this section we give an example of the application of the personalization framework for the dynamic pedagogy-driven creation of a personalized learning experience.

4.3.1. Initiation of the personalization process

If the Learner is a new user has to complete the first 3 steps, else (s)he can start from the Step 4:

- 1) (S)he gives some demographic data
- 2) (S)he gives her/his educational level (primary school, university etc.)
- 3) Depending on the selected learning style taxonomy, an appropriate questionnaire is given to the Learner in order to identify her/his dominant Learning Style. In order to identify the Learner's dominant Honey and Mumford learning style, (s)he completes an appropriate questionnaire. Such a questionnaire could be the one created in 3DE project [Del Corso et. al, 2003], containing 36 questions, since it can be easily completed by the Learners while in parallel gives very good results (see Appendix 7: 3DE Project Questionnaire). However, the Learner is free to choose another learning style (not the dominant one) on which the

personalization process will be based if (s)he wants to, in order to improve other learning styles too. As previously mentioned it has been proven that good Learners have well developed all learning styles.

- 4) In order to initiate the creation of a personalized learning experience:
 - a) The Learner gives some concepts (even as text input) that (s)he wants to learn (e.g. SCORM Content Aggregation Model). An alternative way is to select from a list of existing Courses.
 - b) Taking into account the concept(s) that the Learner has given and her/his Learning Style and Educational Level, an appropriate algorithm similar to the personalization algorithm (in fact a subset of steps from the personalization algorithm) tries to find an appropriate Learning Design that will be used in order to automatically create an exam that will be used as a pre-test in order to:
 - i. Evaluate the previous knowledge of the Learner on the topic that the Learner has selected. That is in fact, evaluating each of the related Learning Objectives associated with the Activities of the Learning Design, in order to create the “Previous Knowledge” part of her/his profile by evaluating the satisfaction of each related Learning Objective (status).
 - ii. Give her/him a hierarchy of related Learning Objectives to further specify his/her learning goals and give a priority. This is formed by the corresponding hierarchy of Learning Objectives that are associated with the Training, Activity Structures and Activities of the selected Learning Design.
 - c) The Learner completes the created pre-test and the satisfaction of the corresponding Learning Objectives is evaluated. A record is added for each Learning Objective in her/his profile with the corresponding status value.
 - d) The Learner may now select a set of Learning Objectives (target Learning Objectives) from the hierarchy of the related Learning Objectives that has been constructed according to the selected Learning Design and give them a priority. (S)he can give a value from 1-10 in order to determine how important is the Learning Objective for her/him (1: little important, 10: absolutely important). The other objectives that exist in his/her profile but have not been selected takes automatically a priority value of 0.0.

The personalization procedure can be now started since all needed input exists: Learning Style, Educational Level, Learning Objectives, Previous Knowledge (also expressed in terms of Learning Objectives), Preferred Planner (optional), Preferred Language (optional) and other Technical Preferences (optional).

There is a close relationship between Learner Goals and Learning Objectives. Learner Goals are usually more general than Learning Objectives, and generally the learning planner (instructor) job is to analyze and further divide those Learner Goals into an appropriate hierarchy of Learning Objectives to satisfy those Goals. As it has been already mentioned, there is no unique way to analyze a Learner Goal to a Learning Objectives hierarchy, and this is highly dependent on the learning style, the educational level and previous knowledge of the Learner.

Let's assume that the Learner in this example has stated that (s)he wants to “comprehend SCORM” and “apply SCORM”. Let's also assume that the goal “comprehend SCORM” already exists in Learner Profile and that this learning objective has been satisfied by a value of 0.3. On the other hand it is assumed that the goal “apply SCORM” is not presented in the Learner Profile as a learning objective mastered in the past, thus it is added in the Learner Profile with a status value of 0.0 as illustrated in Table 4.4. Moreover, let's consider that there are also two learning objectives related with the SCORM domain mastered in the past: “define SCORM” and “define Content Package” with values 0.8 and 0.5 respectively. Table 4.4 shows the Learning Objectives that currently exist in Learner's profile that related with the SCORM domain.

Table 4.4 Total Learning Objectives related with SCORM domain in the Learner Profile. Current target Learning Objectives (Learner Goals) are checked with ✓

Selected Learning Objectives (Learner Goals)	verb	topic	Status	Priority
✓	comprehend	SCORM	0.3	0.5
	define	SCORM	0.8	0.0
	define	Content Package	0.5	0.0
✓	apply	SCORM	0.0	1.0

Let's also assume that the Learner after completing the Honey and Mumford's assessment questionnaire has been found as “Pragmatist” and that (s)he has also the preferences given in Table 4.5.

Table 4.5 Learner's Preferences

Learning Style	Pragmatist
Educational Level	Higher Education
Difficulty	medium
Preferred Planner	Polyxeni Arapi
Language	en-us

The personalization algorithm selects an appropriate Learning Design that will be applied to the dynamic construction of the learning experience. This may be different from the initial Learning Design used for the dynamic creation of the pre-test, since we expect that the Learner has given more specific Learning Objectives using the hierarchy of the selected Learning Design's Learning Objectives and has given a priority to them that influences the selection of the Learning Design.

4.3.2. Selection of appropriate training method

For simplicity reasons we assume that there are four candidate training methods, those presented in Section 4.4.1.3. Of course, other training methods could exist under several learning designs developed for the same domain (SCORM domain) by other learning planners.

To do so, the existing Training Methods are ranked using the following formula, as presented in Section 3.4.4.1:

$$w_{TM} = a_{LV} \cdot w_{LV} + a_{LS} \cdot w_{LS} + a_{EL} \cdot w_{EL} + a_D \cdot w_D + a_P \cdot w_P$$

Where: $a_{LV} + a_{LS} + a_{EL} + a_D + a_P = 1$

w_{LV} is a weight in [0,1] representing the degree of satisfaction Learner's Learning Goals from the Learning Objectives associated (indirectly) with the Training Method. That includes the Learning Objective of its parent Training and the Learning Objectives of its Activity Structures and Activities. This weight is computed as follows:

$$w_{LV} = \frac{\sum_{i=1}^n p_i}{n}, \text{ where } p_1, \dots, p_n \text{ are the priorities of the Learning Goals of the Learner}$$

taking into account only those Learning Goals that correspond to Learning Objectives associated with the Training Method.

$$\text{For TM1: } w_{LV} = \frac{p_{comprehendSCORM} + p_{applySCORM}}{2} = \frac{0.5 + 1}{2} = 0.75$$

$$\text{For TM2: } w_{LV} = \frac{p_{comprehendSCORM} + p_{applySCORM}}{2} = \frac{0.5 + 1}{2} = 0.75$$

$$\text{For TM3: } w_{LV} = \frac{p_{comprehendSCORM}}{1} = \frac{0.5}{2} = 0.25$$

$$\text{For TM4: } w_{LV} = \frac{p_{comprehendSCORM} + p_{applySCORM}}{2} = \frac{0.5 + 1}{2} = 0.75$$

w_{LS} is 1 if the Training Method's associated Learning Style matches the Learning Style of the Learner and 0 otherwise. So, w_{LS} is 1 for TM4 and 0 for TM1, TM2 and TM3.

w_{EL} is a weight in $[0,1]$ representing the degree of similarity between the Educational Level of the Training Method and the Learner's preferred Educational Level. To compute this weight, we assume that the different (ordered) textual values of Educational Level are mapped to $[0,1]$ so that higher Educational Level values are closer to 1. Thus, we map the lowest Educational Level to 0, map the higher Educational Level to 1 and all intermediate values are mapped uniformly in $[0,1]$ with distance between two successive values equal to $1/(n-1)$ where n is the total distinct Educational Level values, as illustrated in Table 4.6.

Table 4.6 Uniform distribution of Educational Level values in $[0,1]$

Uniform distribution in $[0,1]$	Educational Level
0.0	Primary
0.25	Middle
0.5	Secondary
0.75	Further
1.0	Higher Education

Then, w_{EL} is computed as follows:

$$w_{EL} = 1 - (|e_P - e_{TM}| + e_P \cdot f(e_{TM} - e_P))$$

where e_P is the preferred Educational Level of the Learner (the one stored in his profile), e_{TM} is the Educational Level of the Training Method, and f is a function

$$\text{defined as } f(x) = \begin{cases} 0, & x \leq 0 \\ 1, & x > 0 \end{cases}.$$

$$\text{For TM1: } w_{EL} = 1 - (|1 - 0.75| + 1 \cdot f(0.75 - 1)) = 1 - 0.25 + 0 = 0.75$$

Similarly, for TM2-TM4, the w_{EL} is 0.75 since they are associated with the same educational level.

In the same fashion, in order to compute w_D we map the lowest Difficulty to 0, map the higher Difficulty to 1 and all intermediate values are mapped uniformly in $[0,1]$ with distance between two successive values equal to $1/(n-1)$ where n is the total distinct Difficulty values, as illustrated in Table 4.7.

Table 4.7 Uniform distribution of Difficulty values in $[0,1]$

Uniform distribution in $[0,1]$	Difficulty
0.0	very easy
0.25	easy
0.5	medium

0.75	difficult
1.0	very difficult

For TM1: $w_D = 1 - (|0.75 - 0.5| + 0.75 \cdot f(0.5 - 0.75)) = 1 - 0.25 + 0 = 0.75$

Similarly, for TM2-TM4, the w_D is 0.75 since they are associated with the same difficulty.

w_P is 1 if the Training Method's Planner (i.e. the one associated with its parent Training) is one of the Learner's preferred Planners and 0 otherwise. Thus, w_P is 1 for all TMs.

With

$$a_{LV} = 0.3, a_{LS} = 0.2, a_{EL} = 0.2, a_D = 0.2, a_P = 0.1$$

the w_{TM} for each training method is computed as:

$$w_{TM} = 0.3 \cdot w_{LV} + 0.2 \cdot w_{LS} + 0.2 \cdot w_{EL} + 0.2 \cdot w_D + 0.1 \cdot w_P$$

and the results are given in the following table:

Table 4.8 Computation of the weight of each training method

	w_{LV}	w_{LS}	w_{EL}	w_D	w_P	w_{TM}
TM1	0.75	0.0	0.75	0.75	1.0	0.625
TM2	0.75	0.0	0.75	0.75	1.0	0.625
TM3	0.25	0.0	0.75	0.75	1.0	0.475
TM4	0.75	1.0	0.75	0.75	1.0	0.825

From the above table we conclude that TM4 will be selected as the most appropriate for the construction of the personalized learning experience.

4.3.3. Previous knowledge identification

The training method that has been selected in the previous step is used for the construction of an appropriate test in order to evaluate the knowledge of the Learner in the specific subdomain, which scope is defined through the training method's associated learning objectives. Specifically, the goal is to find appropriate Assessment Objects (Assessment Items or Assessment Tests) that will be bound to the training method's activities forming a test that will be able to evaluate how much the Learner has mastered the associated learning objectives. This way, the Learner Profile will be updated either by updating the status of existing Learning Objectives or by adding new Learning Objectives and their corresponding status values that may not exist in his/her profile.

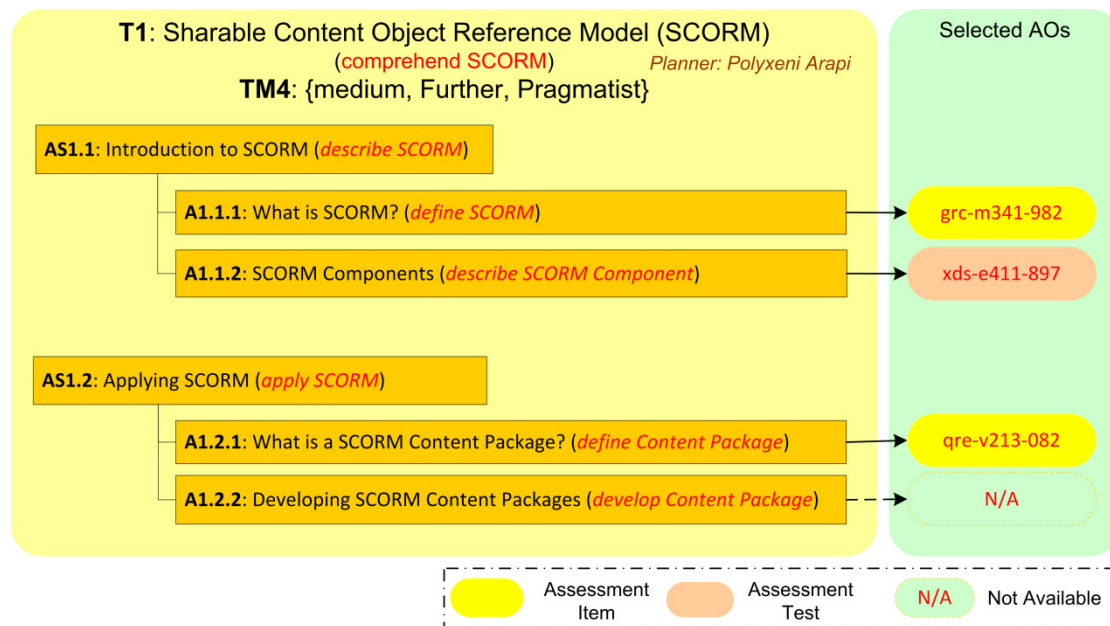


Figure 4.6 Assessment Objects found and bound to TM4 activities forming the Assessment that will evaluate Learner's knowledge

TM4 selected in the previous step is used in order to dynamically construct the Assessment for the evaluation of the Learner's previous knowledge. The Assessment Objects selected after this process are presented in Figure 4.6 and Figure 4.7 shows the exact structure of the generated Assessment.

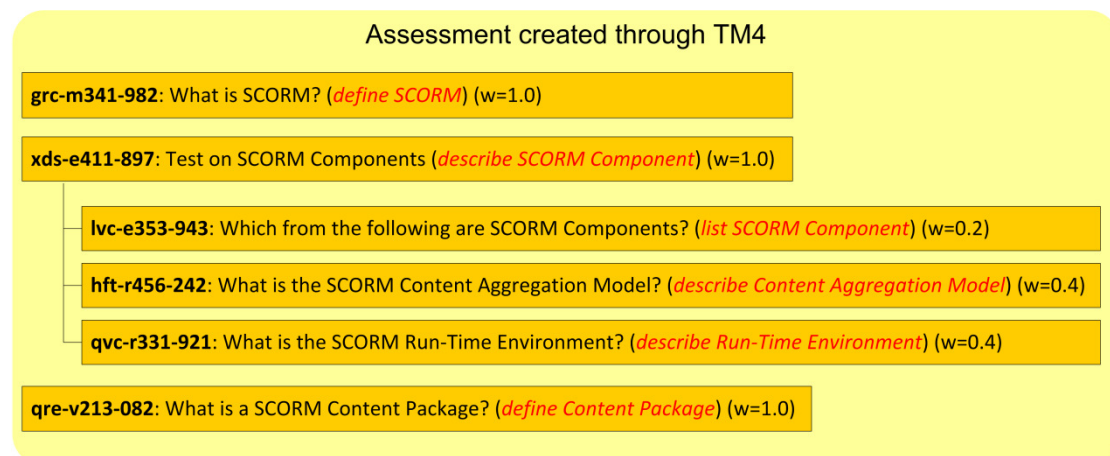


Figure 4.7 Final Assessment created through training method TM4

The Learner answers the questions of the Assessment as illustrated in Figure 4.8.

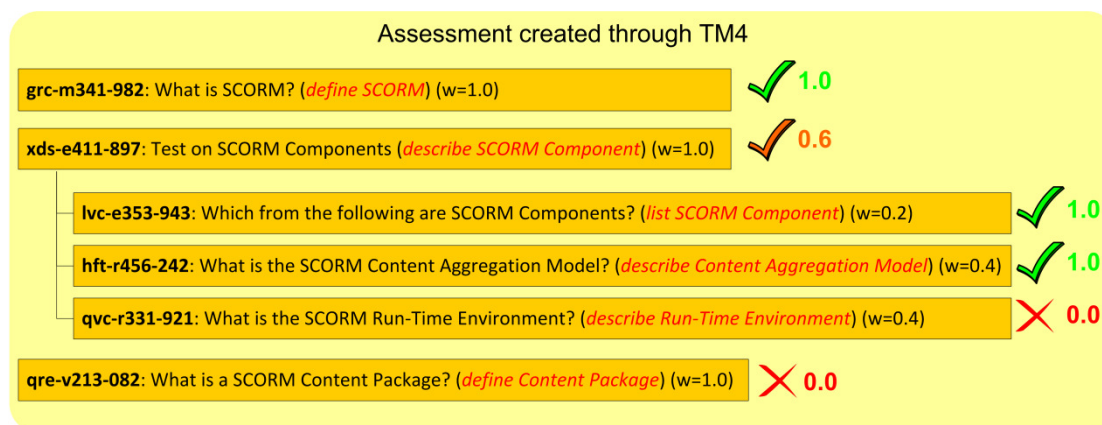


Figure 4.8 Assessment completed by the Learner and score for each learning objective associated with questions (Assessment Items) or questionnaires (Assessment Tests)

After the completion of the Assessment by the Learner, the Learning Objectives in his/her profile are updated as illustrated in Table 4.9.

Table 4.9 Updated Learning Objectives and target goals in Learner Profile after previous knowledge testing

Selected Learning Objectives (Learner Goals)	verb	topic	status
✓	comprehend	SCORM	0.3
	define	SCORM	1.0
	describe	SCORM Component	0.6
	list	SCORM Component	1.0
	describe	Content Aggregation Model	1.0
	describe	Run-Time Environment	0.0
	define	Content Package	0.0
✓	apply	SCORM	0.0

4.3.4. Refinement of the selected training method's structure

When an appropriate Training Method is found its structure is further refined, by removing from it Activity Structures and Activities with Learning Objectives that have been satisfied by the Learner (the Learner can define a threshold value t , so that Learning Objectives with satisfaction value greater than t are considered as satisfied). In this case Activity A.1.1.1 will be removed from the TM4 structure, since it is associated with a Learning Objective that has a status value of 0.8 which is greater than the threshold (threshold=0.5), as illustrated in Figure 4.9.

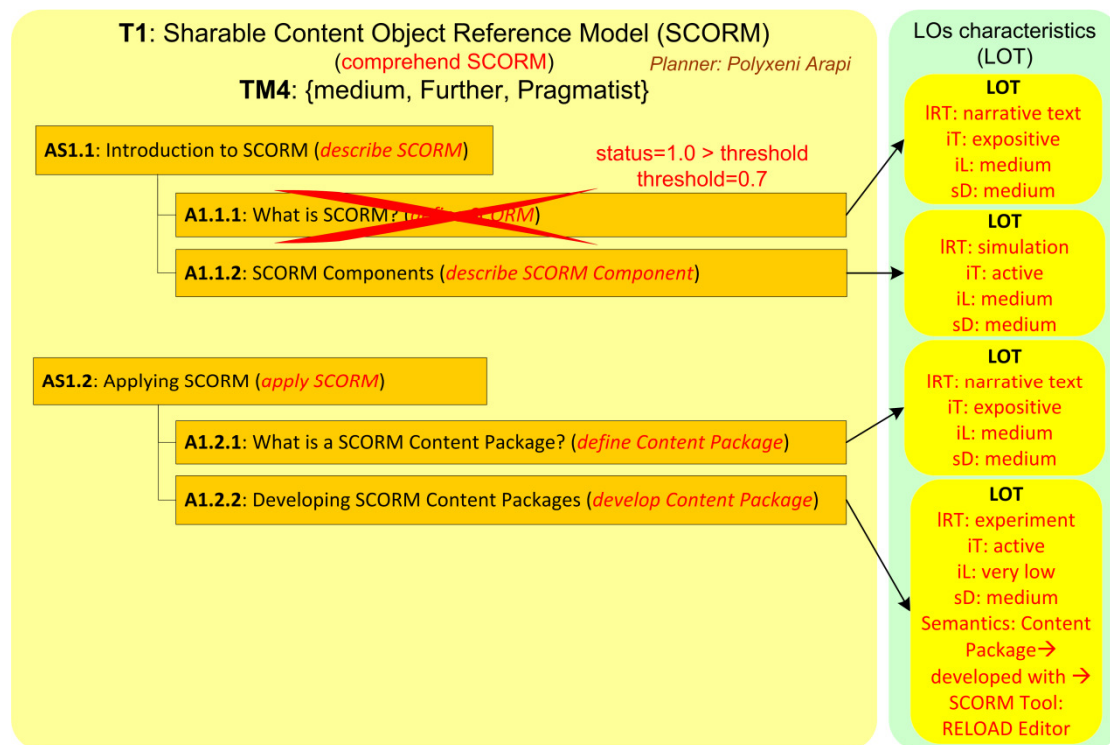


Figure 4.9 Refined training method structure

4.3.5. Retrieval of appropriate learning objects to be bound to the selected training method's activities

The next step is to retrieve appropriate learning objects from the learning object repository to be bound to the activities of the refined training method structure. As described in Section 3.4.4.1, the selection is based on the properties described in the Learning Object Type (LOT) of each activity and some other preferences of the Learner. In order to submit the query with the total learning object requirements, fuzzy filters are used as already described in detail in Section 3.4.4.1.

For example, in order to find the most appropriate learning object for the activity A1.2.2 of the refined structure of TM4 (Figure 4.9), the following fuzzy filter depicted in Figure 4.10 is constructed.

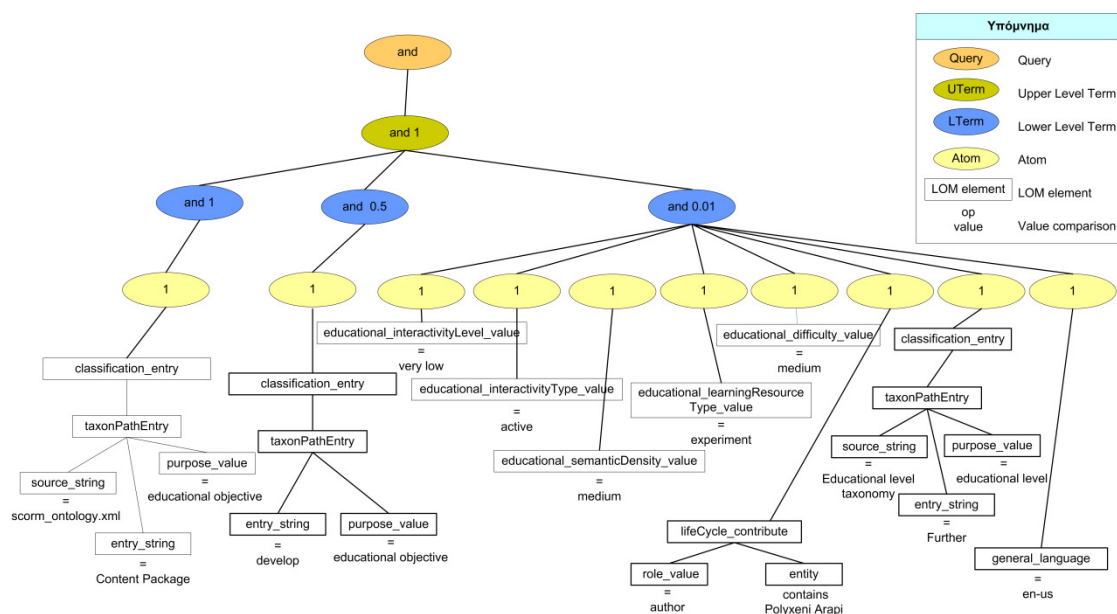


Figure 4.10 Tree representation of the fuzzy filter for the retrieval of learning objects for the activity A1.2.2 of TM4

The same filter is represented in Table 4.10 in XML format.

Table 4.10 Fuzzy filter for the retrieval of learning objects for the activity A1.2.2 of TM4

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  </FuzzyLterm>
</FuzzyUterm>
</FuzzyQuery>

```

After the execution of the query in the learning object repository the learning objects presented in Table 4.11 have been found sorted by their ranking. The first three learning objects are within the allowed range in order to be candidates. Finally, the learning object with the highest rank will be bound to the activity A1.2.2. In this case, this is the learning object with id xds-x491-579.

Table 4.11 Most appropriate LOs for the activity A1.2.2 of TM4 after Fuzzy Filter execution

LO id	LO Title	Rank
xds-x491-579	SCORM Content Packages development with RELOAD Editor Walkthrough	0.9991721854304635761589403973509934
wrc-v715-422	Developing SCORM Content Packages with RELOAD Editor Tutorial	0.996688741721854304635761589403974
kdc-f413-034	Packaging courses with SCORM	0.996688741721854304635761589403974

jkg-c511-906	Inside a SCORM Content Package	0.665562913907284768211920529801400
ffc-g511-425	SCORM Content Packaging	0.665562913907284768211920529801400
gkc-n311-439	SCORM content packages	0.664735099337748344370860927152400

Similarly, appropriate learning objects are found for the other activities of the refined structure of TM4 and the result is illustrated in Figure 4.11.

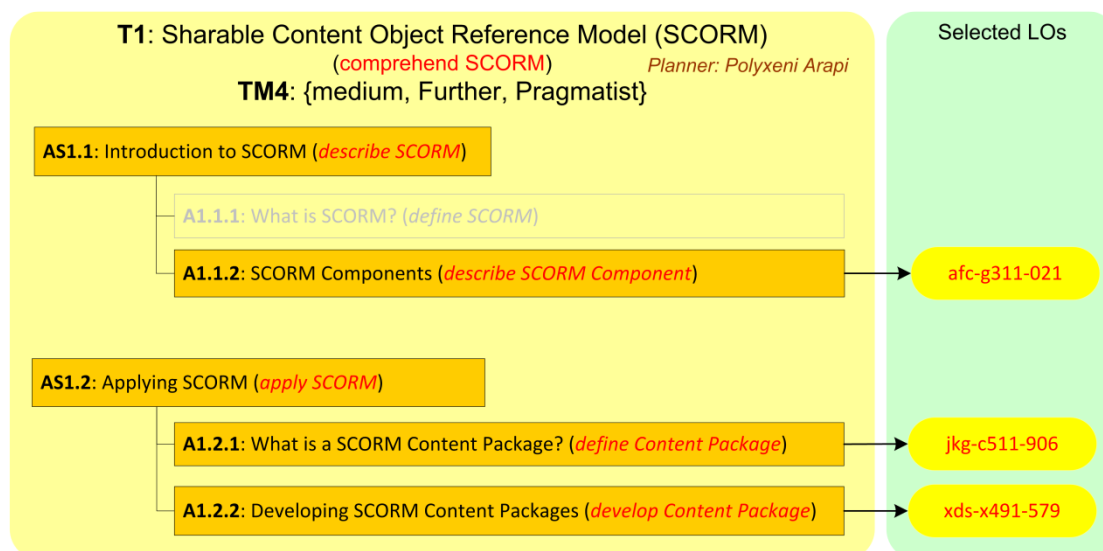


Figure 4.11 Final structure after the binding of the most appropriate learning objects in TM4 activities

4.3.6. Generation of the learning experience (intermediate format)

The intermediate format of the learning experience generated as a result of the personalization process described in the previous section is transformed to an appropriate format (through the Transformation Component) and delivered to the Learner. This could be a SCORM Package, a METS-based representation of a learning experience (see Section 4.1), etc. In Figure 4.12 the intermediate format of Figure 4.11 has been transformed to METS.

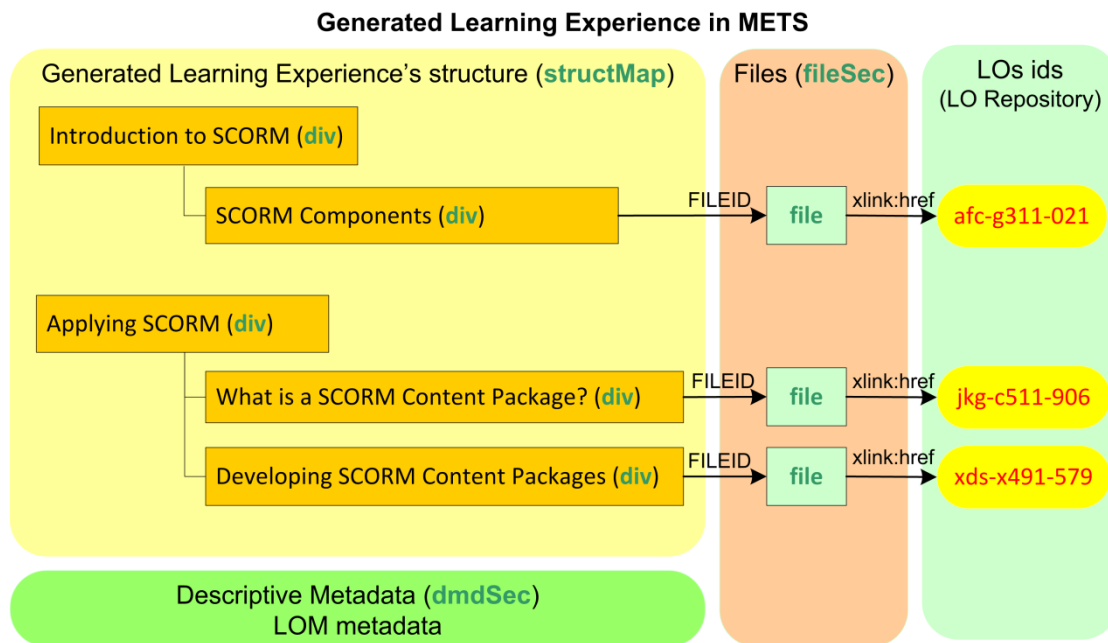


Figure 4.12 Generated Learning Experience transformed to METS

4.4. Summary

In this chapter an example of the application of the framework using Honey & Mumford learning styles has been given. The procedure of setting the environment by the Author has been described including the development of the domain ontology, the development of the learning resources and the development of learning designs and the corresponding training methods. On the other hand, the personalization process has been described as it is being experienced by the Learner including the following phases: a) the initiation of the personalization process, b) the selection of the appropriate training method, c) the previous knowledge identification, d) the refinement of the selected training method's structure, d) the retrieval of appropriate learning objects to be bound to the selected training method's activities, and finally the e) generation of the learning experience (intermediate format).

Chapter 5. IMPLEMENTATION

5.1. Introduction

The proposed framework was initially developed and implemented in DELOS II Network of Excellence in Digital Libraries (IST – Project Record Number 507618) JPA2 subproject, named “Task 5.4 Interoperability of eLearning Applications with Digital Libraries” in a integrated service-oriented architecture above an experimental digital library of audiovisual content [Arapi, Moumoutzis, and Christodoulakis, 2006; Arapi et al., 2007b]. In the context of LOGOS STREP Project (IST-4-027451), named “Knowledge-on-Demand for Ubiquitous Learning” this framework was appropriately adapted in order to satisfy the interoperability and personalization needs in a ubiquitous learning environment [Arapi et al., 2007e]. In the following sections we will present the implementation of the framework in the integrated architecture of LOGOS project, since it is the newest implementation that fully covers and extends the DELOS architecture.

5.2. Implementation in LOGOS Project

Within the LOGOS project, a Knowledge-on-Demand ubiquitous learning platform has been developed in order to bring the uLearning vision into reality, providing effective personalized learning services to support learning anywhere, anytime exploiting alternative delivery channels and related devices that go beyond the traditional web-based learning approaches. The LOGOS platform consists of layered repositories supporting the gradual creation of learning experiences starting from existing content residing at multimedia archives. An Authoring Studio of tools provides all the necessary functionality for learning content creation and supports authoring tasks for certain user roles. Cross-media delivery of learning experiences integrating web-based, mobile and digital TV technologies is handled by special Learning Management System components and publishing services.

Specifically, the LOGOS platform [Moumoutzis, Arapi, and Stockinger, 2008], depicted in Figure 5.1 integrates:

- Appropriate repositories and services for the management of various types of objects:
 - The **Media Server** that manages **Media Objects (MOs)** coming from external content archives,

- The **Digital Objects Repository** that manages **Digital Objects (DOs)** created on top of Media Objects that correspond to Media Objects or parts of them annotated and indexed with administrative and semantic metadata,
- The **Learning Objects Repository** that manages **Learning Objects (LOs)** built on top of Digital Objects and enriched with educational metadata.

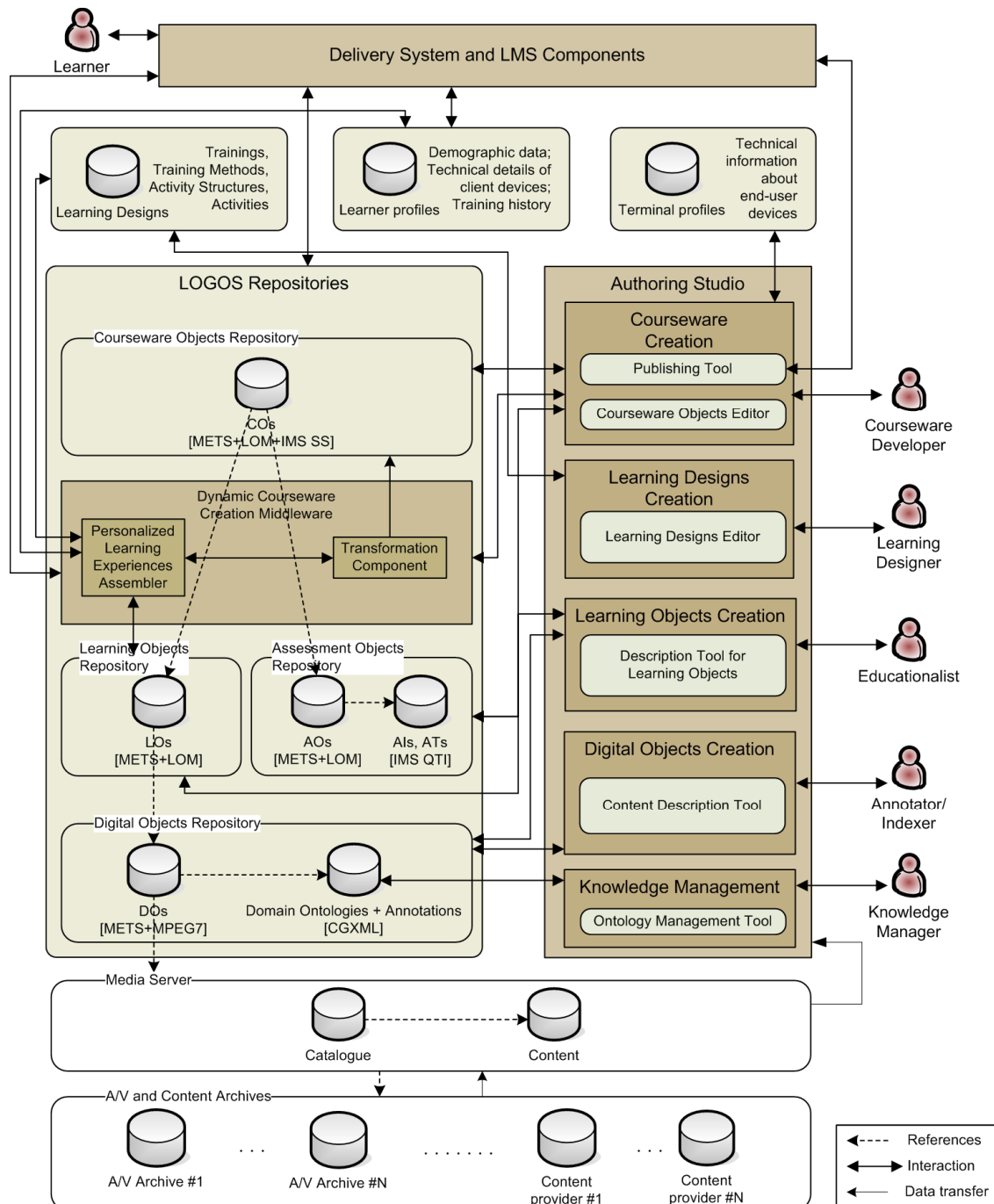


Figure 5.1 LOGOS project overall architecture

- The **Assessment Objects Repository** which resides at the same level with the Learning Object Repository and manages **Assessment Objects (AO)** enriched with educational metadata. Assessment Objects are used to assess the satisfaction of certain learning objectives. Assessment Objects could be simple questions (Assessment Items) or complex questionnaires consisting of Assessment Items (Assessment Tests).
- The **Courseware Objects Repository** that manages **Courseware Objects (CO)** utilizing the underlying Learning Objects and Assessment Objects and corresponding to learning experiences that can be delivered using different delivery devices. They are hierarchies of activities supported with LOs or AOs and they are described with educational metadata and possibly sequencing and navigation metadata.
- The **Dynamic Courseware Creation Middleware** residing between the Learning Objects Repository level and the Courseware Objects Repository level and used for the automatic creation of personalized courseware according to specific learning needs expressed in **Learner Profiles** and using a set of abstract training scenarios (**Learning Designs**). This service can be exploited both by Learners as learning experiences and by courseware authors providing them a semi-automatic method for the creation of courseware.
- An **Authoring Studio** that consists of tools for the creation and editing of the above types of objects as well as for the creation of abstract training scenarios (Learning Designs) in order to support the dynamic creation of personalized learning experiences and for the publishing of courseware objects to different delivery platforms. The tools of the Authoring Studio are the following:
 - The **Ontology Management Tool**: It is used for the creation and management of domain multilingual domain ontologies with graphical, intuitive and user friendly interfaces that could be efficiently used by domain experts (knowledge managers). The tool can create and manage knowledge inference rules, constraints and templates in order to reduce the indexation effort.
 - The **Content Description Tool**: Performs segmentation and indexing of the digital audiovisual objects, their annotation, semantic description and necessary format transformations. It also provides multilingual support functionality. It utilizes a Graphical Conceptual Graph Querying Tool (a component of the Content Description Tool) to perform searches on the existing digital objects and selects the appropriate ones for additional

annotation processes. It also utilizes semantic indexing templates created by the Ontology Management Tool to guide the annotation process.

- The **Description Tool for Learning Objects**: It is used for the pre-selection and organization into a hierarchy of relevant audiovisual segments and files for a given pedagogical or para-pedagogical use. This tool essentially provides the means to create educational metadata for digital objects (and combinations of them) so that reusable Learning Objects could be created. These reusable Learning Objects could be exploited for courseware creation or as elements facilitating learning processes (e.g. material that a teacher can use in the classroom).
- The **Learning Designs Editor**: Used to create learning designs (abstract training scenarios) used for the automatic creation of personalized learning experiences that may be used either by learners or by courseware developers.
- The **Courseware Objects Editor**: Used to create static Courseware Objects, including quizzes (learner assessments). It utilizes the Publishing Tool to provide a preview of the constructed courseware. It also utilizes the search services of the Learning Objects Repository to perform searches for reusable learning objects that may be used in the courseware. It also exploits the dynamic courseware creation functionality of the Dynamic Courseware Creation Middleware of the LOGOS Repositories in order to facilitate the creation of Courseware Objects by further editing dynamically created courseware.
- The **Publishing Tool**: Used to publish indexed, annotated, translated and enhanced audiovisual segments in appropriate formats to be used by Learners using different devices such as PCs, mobile phones and ITV.
- **Learning Management System components** for the delivery of courseware to Learners encapsulating functionality to adapt the learning material to individual user needs and context as well as to track user's progress and update the user related information represented in Learner Profiles.

5.2.1. Formulation and description of LOGOS objects

LOGOS follows a hierarchical approach in the categorization of the objects it manages, and their representation is based on the interoperability framework presented in this thesis. There are several reasons and advantages of this approach:

- It makes possible the reusability of lower level objects from higher level objects and reduces the development cost of learning content.
- It efficiently supports the gradual development of learning resources starting from existing media that reside in external digital libraries, while in parallel it supports the delivery of this material using multiple delivery channels.
- It makes possible the exploitation and delivery of the underlying objects to different channels (devices).

The above are possible, since this approach allows for:

- Integrated description of objects at each level using several appropriate (metadata) schemes to represent the different aspects of objects.
- References to objects residing at lower levels without repeating their information at the current level. Generally, objects residing at a certain level are able to reference objects at the level underneath. Moreover, this flexible representation of objects allows for appropriate adaptation/transformation of objects at run-time in order to support cross-media delivery of learning experiences.

The following figure illustrates the relation among COs, LOs, AOs, DOs and Media Objects residing in corresponding repositories and the Media Server.

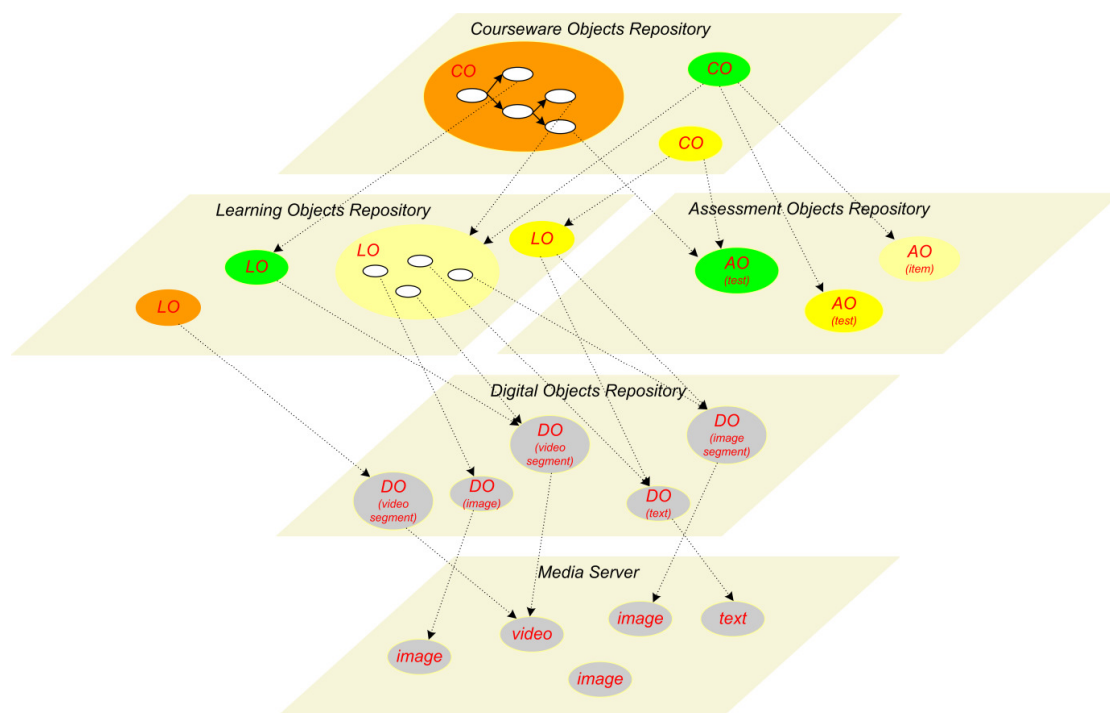


Figure 5.2 Relation among COs, LOs, AOs, DOs and Media Objects residing in corresponding repositories and the Media Server

Figure 5.3 illustrates how the interoperability framework that exploits METS is applied in the case of LOGOS for the representation and description of DOs, LOs, AO and COs.

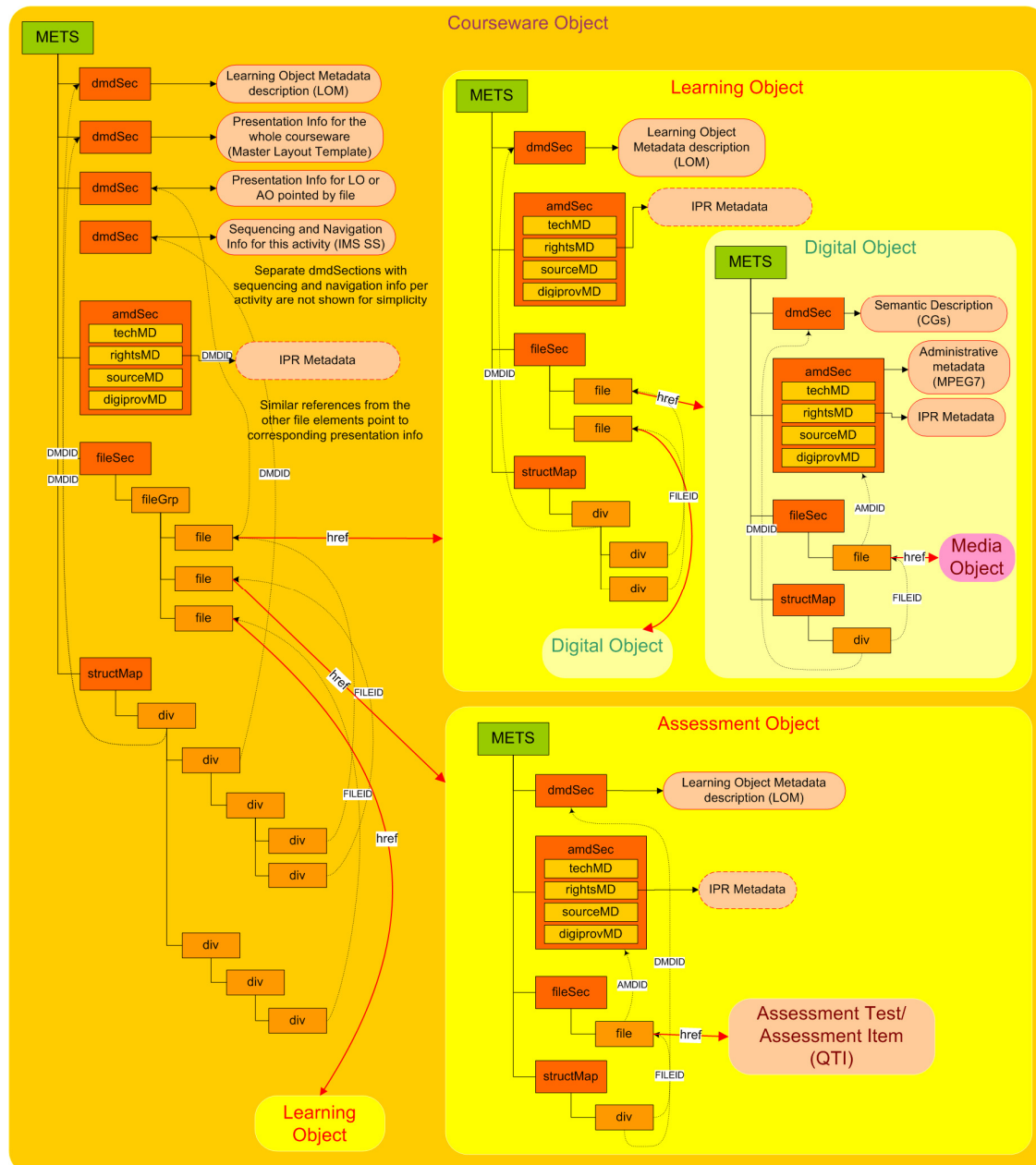


Figure 5.3 COs, LOs, AOs, DOs, MOs and their relations using METS according to the interoperability framework

- DOs are described both with semantic information and administrative information. The descriptive metadata section (`dmdSec`) of METS is used to incorporate semantic description expressed with CoGXML⁶ (a representation format for conceptual graphs) and the administrative metadata section (`amdSec`) in order to incorporate administrative metadata expressed with MPEG7. The

⁶ http://cogitant.sourceforge.net/cogitant_html/cogxml.html

fileSec is used to point to the parent media object residing at the Media Server, from which the current DO has evolved.

- LOs are described with IEEE LOM using the dmdSec. Since LOM incorporates in its model entries for administrative information, the amdSec of METS is not separately used in this case for representing administrative metadata. The fileSec consisting of file elements is used to point to the LO's constituent parts (DOs) via identifiers.
- AO are also described with LOM metadata. While LOs containing DOs are built to fulfill specific learning objectives, assessment-type LOs are used to evaluate learning objectives. IMS QTI descriptions are used for the representation of assessments that are referenced from the METS description.
- COs are also described with LOM via the dmdSec of METS. The structMap section is used to represent the CO's structure consisting of a hierarchy of activities (expressed with div) that can take place during the learning process using multiple devices. Each activity (div) is supported by a LO residing at the LO repository and pointed to through file element via identifiers. A CO as a whole and its constituent LOs could reference using dmdSec elements some presentation info that is exploited at run-time to render the learning material in the target devices.

5.2.2. LOGOS Repositories services

Apart from the Media Server, the specification of the services offered by LOGOS repositories follows the recommendations of IMS Digital Repositories Interoperability specification [IMS DRI, 2003] as proposed in the interoperability framework presented in this thesis.

The functions that are supported are:

- Search/Expose: The ability to locate an appropriate object. This can include the ability to browse. The Search function defines the searching of metadata for assets “exposed” by repositories. A repository can be searched directly or using an intermediate search engine.
- Gather/Expose: Obtain metadata about objects in other repositories for federated searches and information clearinghouse. The Gather function allows the aggregation of meta-data from repositories for use in subsequent searches. The Gather function may actively request meta-data from a repository (“pull”) or it can subscribe to a service that notifies the Gather component when meta-data in the repository has been added, deleted or changed (“push”).

- **Submit/Store:** Provide an object (content and metadata) to a repository for storage. Submit places an object into a repository. Store allows a repository to store the object so that it may be retrieved later.
- **Request/Deliver:** These functions allow a system user to request learning objects or other resources located with the Search function. The Search function returns repository object identifiers as a list of locations or as a method, such as a Digital Object Identifier (DOI), that resolves to one or more locations. The location returned by Search resolves to a URL that can then be used to Request the object. The protocol used to deliver a requested learning object depends on the object type.
- **Alert/Expose:** These functions provide a method for notifying interested parties of any changes made to content stored in a repository or repository system. Whenever repository has new metadata matching subscribe parameters, it sends an alert message to the subscribers. These functions are not considered in Phase 1 of the DRI specification.

In the scope of LOGOS project the following functions are relevant: Search/Expose, Submit/Store, Request/Deliver and Alert/Expose.

The services implemented for the management of objects in DO, LO, AO and CO repositories are presented in Table 5.1 categorized according to IMS DRI.

Table 5.1 Summarization of DO, LO, AO and CO repositories implemented services according to IMS DRI recommendations

	DO Repository	LO Repository	AO repository	CO repository
Search/ Expose	search_DO	search_LO fuzzy_search_LO	search_AO fuzzy_search_AO	search_CO fuzzy_search_CO
Submit/ Store	checkin_Description checkout_Description get_DescriptionList	create_LO update_LO delete_LO render_LO createCopyOfRendered_LO	create_AO update_AO delete_AO render_AO createCopyOfRendered_AO	create_CO update_CO delete_CO render_CO createCopyOfRendered_CO
Request/ Deliver	get_DO get_All_DO_of_media	get_LO get_All_DO_in_LO get_LO_summary	get_AO get_AO_summary	get_CO get_All_LO_in_CO get_CO_summary
Alert/ Expose	alert_for_DO reuse_alert_for_DO delete_alert_for_DO check_alert_for_DO retrieve_user_alerts_for_DO retrieve_all_alerts_for_DO	alert_for_LO reuse_alert_for_LO delete_alert_for_LO check_alert_for_LO retrieve_user_alerts_for_LO retrieve_all_alerts_for_LO		alert_for_CO reuse_alert_for_CO delete_alert_for_CO check_alert_for_CO retrieve_user_alerts_for_CO retrieve_all_alerts_for_CO

In the following sections the detailed descriptions of the services that are provided by the Digital Objects, Learning Objects, Assessment Objects and Courseware Objects

repositories using the IMS DRI categorization are presented [Moumoutzis, Arapi, and Stockinger, 2008; Stylianakis, 2008].

5.2.2.1. Digital Objects Repository services

This section presents the services offered by the Digital Objects Repository grouped in the categories identified by the IMS DRI specification (Search/Expose, Submit/Store, Request/Deliver and Alert/Expose).

5.2.2.1.1 Search/Expose

search_DO		
This service is used in order to search for DOs satisfying a given Boolean MPEG7 filter which is composed of a Media filter and a general DO filter composed with a conceptual graph.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
MPEG7filter	String	It corresponds to an xml document that contains the xml representation of the Boolean Mpeg7 filter to be used in order to search for DOs. The structure and semantics of Boolean Mpeg7 filters are given in Appendix 5.1
semanticFilter	String	It corresponds to an xml document that contains the xml representation of a conceptual graph used as a filter in order to semantically search for DOs. The syntax of this graph is expressed using the cogxml format.
<i>Service output:</i>		
Parameter name	Parameter type	Description
search_DOReturn	Vector	An array containing the DOIds of the DOs that satisfy the query parameters
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

Boolean Mpeg7 filters are used in order to make searches in the Digital Objects Repository. These filters are clearly separated at the uppermost level in two separated branches: the first one for DO filters and the second one for Media Filters. These distinct branches are connected by an implicit AND operator and both are structured as three level Boolean syntax trees like the ones defined in Section 3.4.4.1 for the Boolean LOM Filters. Lower level nodes contain triples of the form <attr, op, value> that specify parameters on Mpeg7 attributes that a DO should satisfy. For example such triples could be:

- <DO/Title,contains,"icons">
- <Media/Availability/Region,=,Hungary>

In Appendix 5.1, the XML schema for the specification of MPEG7 filters is given.

5.2.2.1.2 Submit/Store

checkin_Description		
This service creates or updates a description		
<i>Service input:</i>		
Parameter name	Parameter type	Description
incomingDesc	Document	Corresponds to an xml document that contains the xml representation of the new Description.
<i>Service output: none</i>		
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

checkout_Description		
This service loads an existing description from the DO repository.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
DescId	string	The DescId of the description that should be loaded
<i>Service output:</i>		
Parameter name	Parameter type	Description
descReturn	Document	An XML document containing the description

get_DescriptionList		
This service returns the list of descriptions.		
<i>No Service input:</i>		
<i>Service output :</i>		
Parameter name	Parameter type	Description
descriptionList	String	An XML document containing title and Id couples for all available descriptions
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.1.3 Request/Deliver

get_DO		
This service returns the DO description (METS document) of a specific DO (its DOId is given as input to the service).		

Service input:

Parameter name	Parameter type	Description
DOid	string	The DOid of the DO to be retrieved.

Service output:

Parameter name	Parameter type	Description
get_DOReturn	string	The METS document in the form of a string that corresponds to the description of the DO requested.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

get_All_DO_of_media

Get all DOids of a given media i.e.: all the DOs that are contained in all the descriptions related to this Media. The metadata and semantic annotations of these DOs can be later retrieved using the get_DO service of the DO repository.

Optionally, this query may be constrained by the name of a domain (ontology).

Notion of description “point of view”

The point of view of a description is defined by the ontological resources used to lead / control the description according a given domain (human science, history, arts ...). A given media may be described in different ways according these domains and so may support different descriptions.

Under this aspect we can deduce:

The domain is a relevant notion for the author who want to create a courseware, so the service described here that is able to retrieve all the DOs of a given domain for a given media may is needed.

On the other hand retrieving all the DOs of a given media (whatever the domain) can have some utility in some cases. This can be done by considering the domain parameter as optional.

Service input:

Parameter name	Parameter type	Description
Media_id	string	The Media identifier of the media for which the related DOs are requested (whatever the description).
Ontology_id	string	The ontology identifier (optional); if this parameter is empty, all the DOs for a given media will be returned. If an Id is given all the DOs belonging to any description done according to this specific ontology are returned.

Service output:

Parameter name	Parameter type	Description
get_All_DO_in_MediaReturn	Vector	An array containing the DOids of the DOs that are contained in all the descriptions related to the media or to the description(s) related to the media according to a given ontology domain.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.1.4 Alert/Expose

alert_for_DO

This service is used to register an alert for a user interested in finding new DOs created or updated that satisfy a specific filter. To keep the implementation more flexible the notification of the user is to be done through special services that allow for the retrieval of objects satisfying an alert (see service check_alert_for_DO below).

Service input:

Parameter name	Parameter type	Description
MPEG7filter	string	It corresponds to an xml document that contains the xml representation of the Boolean Mpeg7 filter to be used in order to search for DOs. The structure and semantics of Boolean Mpeg7 filters are given in Appendix 5.1.
semanticFilter	string	It corresponds to an xml document that contains the xml representation of a conceptual graph used as a filter in order to semantically search for DOs. The syntax of this graph is expressed using the cogxml format.
comment	string	A descriptive comment for the alert.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
alert_for_DOReturn	string	This string contains the unique alertid that is given to the newly created alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

reuse_alert_for_DO

This service is used to register an existing alert for a specific user. The reason behind this service is that more than one user may be interested in the same alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
reuse_alert_for_DOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_alert_for_DO

Removes the specified alert for the specified user. If the alert has no more users registered, then the alert is removed from the repository.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
delete_alert_for_DOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

check_alert_for_DO

This service is used to check in the DO repository if DOs exist that satisfy the specified alert. This checking could be done in the whole repository, when the checkNewObjects flag is false, or in the set of newly created and updated objects (i.e. the ones created or updated from the previous time the alert was checked for the specified user), when the checkNewObjects flag is true. The service returns the list of DOIds that satisfy the alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.
checkNewObjects	boolean	This parameter is a Boolean flag. If its value is 'true' then the service returns only the newly created or updated objects that satisfy the alert. If it is 'false' then all the DOs satisfying the alert are returned.

Service output:

Parameter name	Parameter type	Description
check_alert_for_DOReturn	Vector	An array containing the DOIds of the DOs that satisfy the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_user_alerts_for_DO

Retrieves all the alerts registered for a specific user.

Service input:

Parameter name	Parameter type	Description
userid	string	The userid of the user whose alerts are to be returned.

Service output:

Parameter name	Parameter type	Description
retrieve_user_alerts_for_DOReturn	Vector	An array containing the information regarding the alerts registered for the user specified in the parameter of the service. For each alert the service returns the alertId, the corresponding Boolean Mpeg7 filter, the semantic filter of the alert and the comment of the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_all_alerts_for_DO

Retrieves all the alerts registered in the DO repository.

Service input:

No input parameter.

Service output:

Parameter name	Parameter type	Description
retrieve_all_alerts_for_DOReturn	Vector	An array containing the information regarding the alerts registered in the DO repository. For each alert the service returns the alertId, the userids of the users that have registered this alert, the corresponding Boolean Mpeg7 filter, and the semantic filter of the alert and the comment of the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.2. Learning Objects Repository services

This section presents the services offered by the Learning Objects Repository grouped in the categories identified by the IMS DRI specification (Search/Expose, Submit/Store, Request/Deliver and Alert/Expose). Before proceeding with the description of the services it should be noted that the state (EDITING or RENDERED) of LOs is represented using the lifecycle/status LOM element. In particular the ‘draft’ value of this element is used to represent a LO that is in EDITING state while the ‘final’ value is used to represent a LO that is in RENDERED state.

5.2.2.2.1 Search/Expose

search_LO		
This service is used in order to search for LOs satisfying a given Boolean LOM filter and containing DOs that satisfy given MPEG7 and semantic filters.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
booleanLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Boolean LOM filter to be used in order to search for qualifying LOs. The structure and semantics of Boolean LOM filters are given in Appendix 5.3.
MPEG7filter	string	It corresponds to an xml document that contains the xml representation of the Boolean MPEG7 filter to be used in order to search for DOs. The structure and semantics of Boolean MPEG7 filters are given in Appendix 5.1.
semanticFilter	string	It corresponds to an xml document that contains the xml representation of a conceptual graph used as a filter in order to semantically search for DOs. The syntax of this graph is expressed using the cogxml format.
<i>Service output:</i>		
Parameter name	Parameter type	Description
search_LOReturn	Vector	An array containing the LOids of the LOs that satisfy the given filters
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

fuzzy_search_LO		
This service is used in order to search for LOs satisfying a given Fuzzy LOM filter and containing DOs that satisfy the given MPEG7 and semantic filters. The result is a ranked list of the qualifying LOs.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
fuzzyLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Fuzzy LOM filter to be used in

		order to search for qualifying LOs. The structure and semantics of Fuzzy LOM filters are given in Appendix 5.4.
MPEG7filter	string	It corresponds to an xml document that contains the xml representation of the Boolean MPEG7 filter to be used in order to search for DOs. The structure and semantics of Boolean MPEG7filters are given in Appendix 5.1.
semanticFilter	string	It corresponds to an xml document that contains the xml representation of a conceptual graph used as a filter in order to semantically search for DOs. The syntax of this graph is expressed using the cogxml format.

Service output:

Parameter name	Parameter type	Description
fuzzy_search_LOReturn	Vector	An array containing the <LOid, rank> pairs of the LOs that satisfy the given filter and the corresponding ranking of each LO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.2.2 Submit/Store

create_LO		
This service creates a new LO and gives a new LOid to it that is returned by the service. The new LO is set in EDITING state by default. Creating a LO involves submission and storage of the LO description (METS document including LOM metadata) to the LO repository.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
incomingDoc	Document	It corresponds to an xml document with the representation of the new LO using METS as described in Chapter 3.
<i>Service output:</i>		
Parameter name	Parameter type	Description
create_LOReturn	string	A string representing the unique LOid given to the newly created LO.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

update_LO		
This service updates an existing LO. The LO should be in EDITING state in order to be updated. If the LO is in RENDERED state, no update is made and an appropriate error message is returned. Updating a LO		

involves submission and storage of the new LO description (METS document including LOM metadata) to the LO repository.

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO that should be updated.
newDoc	string	An xml document given as a string that contains the updated xml representation of the LO. It corresponds to an xml document with the representation of the new LO using METS as described in Chapter 3.

Service output:

Parameter name	Parameter type	Description
update_LOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_LO

This service deletes an existing LO. The LO should be in EDITING state in order to be deleted. If the LO is in RENDERED state, no deletion is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO that should be deleted.

Service output:

Parameter name	Parameter type	Description
delete_LOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

render_LO

This service puts an existing LO in RENDERED state. If the LO is already in RENDERED state, no change is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO that should be put in RENDERED state.

Service output:

Parameter name	Parameter type	Description
render_LOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

createCopyOfRendered_LO

This service creates a new LO that is a copy of an existing LO in RENDERED state. The new LO is put in EDITING state. Using this service new LOs can be created that are based on existing ones and further edited. The unique LOid of the newly created LO is returned. If the source LO is not in RENDERED state, no new LO is created and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO in RENDERED state that will be copied.

Service output:

Parameter name	Parameter type	Description
createCopyOfRendered_LOReturn	string	This string contains the unique LOid given to the newly created LO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.2.3 Request/Deliver**get_LO**

This service returns the LO description (METS document) of a specific LO (its LOid is given as input to the service).

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO to be retrieved.

Service output:

Parameter name	Parameter type	Description
get_LOReturn	string	The METS document in the form of a string that corresponds to the description of the LO requested.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

get_All_DO_in_LO

Get all DOids of the DOs that are contained in a specific LO. The metadata and semantic annotations of these DOs can be later retrieved using the corresponding services of the DO repository.

Service input:

Parameter name	Parameter type	Description
LOid	string	The LOid of the LO for which the constituent DOs are requested.

Service output:

Parameter name	Parameter type	Description
get_All_DO_in_LOReturn	Vector	An array containing the DOids of the DOs that are contained in the LO whose LOid is given as an input parameter to the service.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

get_LO_summary

This service retrieves the specified LOM elements (metadata) for particular LOs. The purpose of this service is to give the possibility to retrieve specific metadata for a set of LOs in order to support various LO browsing scenarios including the presentation of particular LO metadata after a search.

Service input:

Parameter name	Parameter type	Description
LOids	Vector	The LOids of the LOs for which specific metadata elements (those specified by the second parameter) are requested.
lomElements	Vector	An array of LOM elements that should be retrieved for each one of the LOs specified in the first parameter.

Service output:

Parameter name	Parameter type	Description
get_LO_summaryReturn	Vector	An array containing the requested metadata elements for each one of the specified LOs. Each entry in this array is another array (Vector) that contains the LOid of a LO and the values of the LOM elements requested.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.2.4 Alert/Expose**alert_for_LO**

This service is used to register an alert for a user interested in finding new LOs created or updated that satisfy a specific Boolean LOM filter. To keep the implementation more flexible the notification of the user is to be done through special services that allow for the retrieval of objects satisfying an alert (see service `check_alert_for_LO` below).

Service input:

Parameter name	Parameter type	Description
booleanLOMfilter	string	The Boolean LOM filter that specifies what kind of LOs is requested by the user registering the alert. The structure and semantics of Boolean LOM filters are given in Section 3.4.4.1.
comment	string	A descriptive comment for the alert.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
alert_for_LOReturn	string	This string contains the unique alertid that is given to the newly created alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

reuse_alert_for_LO

This service is used to register an existing alert for a specific user. The reason behind this service is that more than one user may be interested in the same alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
reuse_alert_for_LOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_alert_for_LO

Removes the specified alert for the specified user. If the alert has no more users registered, then the alert is removed from the repository.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
delete_alert_for_LOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

check_alert_for_LO

This service is used to check in the LO repository if LOs exist that satisfy the specified alert. This checking could be done in the whole repository, when the checkNewObjects flag is false, or in the set of newly created and updated objects (i.e. the ones created or updated from the previous time the alert was checked for the specified user), when the checkNewObjects flag is true. The service returns the list of LOids that satisfy the alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.
checkNewObjects	boolean	This parameter is a Boolean flag. If its value is 'true' then the service returns only the newly created or updated objects that satisfy the alert. If it is 'false' then all the LOs satisfying the alert are returned.

Service output:

Parameter name	Parameter type	Description
check_alert_for_LOReturn	Vector	An array containing the LOids of the LOs that satisfy the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_user_alerts_for_LO

Retrieves all the alerts registered for a specific user.

Service input:

Parameter name	Parameter type	Description
userid	string	The userid of the user whose alerts are to be returned.

Service output:

Parameter name	Parameter type	Description
retrieve_user_alerts_for_LOReturn	Vector	An array containing the information regarding the alerts registered for the user specified in the parameter of the service.

		For each alert the service returns the alertid, the corresponding Boolean LOM filter of the alert and the comment of the alert.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_all_alerts_for_LO		
Retrieves all the alerts registered in the LO repository.		
<i>Service input:</i> No input parameter.		
<i>Service output:</i>		
Parameter name	Parameter type	Description
retrieve_all_alerts_for_LOReturn	Vector	An array containing the information regarding the alerts registered in the LO repository. For each alert the service returns the alertid, the userids of the users that have registered this alert, the corresponding Boolean LOM filter of the alert and the comment of the alert.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.3. Assessment Objects Repository services

This section presents the services offered by the Assessment Objects Repository grouped in the categories identified by the IMS DRI specification (Search/Expose, Submit/Store, and Request/Deliver). Before proceeding with the description of the services it should be noted that the state (EDITING or RENDERED) of Assessment Objects (AOs) is represented using the lifecycle/status LOM element. In particular the 'draft' value of this element is used to represent an AO that is in EDITING state while the 'final' value is used to represent an AO that is in RENDERED state. Moreover the educational/learningResourceType element is used to represent the type of AOs: The value 'exercise' is used to represent assessment items and the value 'questionnaire' is used to represent assessment tests.

5.2.2.3.1 Search/Expose

search_AO
This service is used in order to search for AOs satisfying a given Boolean LOM filter.
<i>Service input:</i>

Parameter name	Parameter type	Description
booleanLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Boolean LOM filter to be used in order to search for qualifying AOs. The structure and semantics of Boolean LOM filters are given in Section 3.4.4.1 and are appropriately adapted in order to refer to AOs.
searchFor	string	It specifies what types of assessment objects should be searched for. If the value of this parameter is 'test', then only assessments tests satisfying the Boolean filter are returned. If the value is 'item' then only assessment items satisfying the Boolean filter are returned. If the value is 'all' then both assessment tests and assessment items are returned.

Service output:

Parameter name	Parameter type	Description
search_AOReturn	Vector	An array containing the AOids of the AOs that satisfy the given filter

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

fuzzy_search_AO

This service is used in order to search for AOs satisfying a given Fuzzy LOM filter. The result is a ranked list of the qualifying AOs.

Service input:

Parameter name	Parameter type	Description
fuzzyLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Fuzzy LOM filter to be used in order to search for qualifying AOs. The structure and semantics of Fuzzy LOM filters are given in Section 3.4.4.1 and are appropriately adapted in order to refer to AOs.
searchFor	string	It specifies what types of AOs should be searched for. If the value of this parameter is 'test', then only assessments tests satisfying the fuzzy filter are returned. If the value is 'item' then only assessment items satisfying the fuzzy filter are returned. If the value is 'all' then both assessment tests and assessment items are returned.

Service output:

Parameter name	Parameter type	Description
fuzzy_search_AOReturn	Vector	An array containing the <AOid, rank> pairs of the AOs that satisfy the given filter and the corresponding ranking of each AO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.3.2 Submit/Store

create_AO

This service creates a new AO and gives a new AOid to it that is returned by the service. The new AO is set in EDITING state by default. Creating an AO involves submission and storage of the AO description (METS document including LOM metadata) and the corresponding QTI description to the AO repository. The QTI description stored in the repository receives the same AOid.

Service input:

Parameter name	Parameter type	Description
incomingDocMETS	Document	It corresponds to an xml document with the representation of the new AO using METS as described in Chapter 3.
incomingDocQTI	Document	It corresponds to an xml document that contains the xml representation of the content of the AO in QTI.

Service output:

Parameter name	Parameter type	Description
create_AOReturn	string	A string representing the unique AOid given to the newly created AO that also identifies the corresponding QTI xml document.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

update_AO

This service updates an existing AO. The AO should be in EDITING state in order to be updated. If the AO is in RENDERED state, no update is made and an appropriate error message is returned. Updating an AO involves submission and storage of the new AO description (METS document including LOM metadata) and QTI description to the AO repository.

Service input:

Parameter name	Parameter type	Description
AOid	string	The AOid of the AO that should be updated.
newDocMETS	string	An xml document given as a string with the representation of the new LO using METS as described in Chapter 3.
newDocQTI	string	An xml document given as a string that contains the updated xml representation of the QTI description of the AO.

Service output:

Parameter name	Parameter type	Description
update_AOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_AO

This service deletes an existing AO. The AO should be in EDITING state in order to be deleted. If the AO is in RENDERED state, no deletion is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
AOid	string	The AOid of the AO that should be deleted.

Service output:

Parameter name	Parameter type	Description
delete_AOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

render_AO

This service puts an existing AO in RENDERED state. If the AO is already in RENDERED state, no change is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
AOid	string	The AOid of the AO that should be put in RENDERED state.

Service output:

Parameter name	Parameter type	Description
render_AOReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

createCopyOfRendered_AO

This service creates a new AO that is a copy of an existing AO in RENDERED state. The new AO is put in EDITING state. Using this service new AOs can be created that are based on existing ones and further edited. The unique AOid of the newly created AO is returned. If the source AO is not in RENDERED state, no new AO is created and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
AOid	string	The AOid of the AO in RENDERED state that will be copied.

Service output:

Parameter name	Parameter type	Description
createCopyOfRendered_AOReturn	string	This string contains the unique AOid given to the newly created AO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.3.3 Request/Deliver**get_AO**

This service returns the AO description (METS document) of a specific AO (its AOid is given as input to the service).

Service input:

Parameter name	Parameter type	Description
AOid	string	The AOid of the AO to be retrieved.

Service output:

Parameter name	Parameter type	Description
get_AOReturn	Vector	An array of two elements: The first element is the METS document in the form of a string that corresponds to the AO requested. The second element is the QTI description of the AO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	String	An error message that corresponds to the above error code.

get_AO_summary

This service retrieves the specified LOM elements (metadata) for particular AOs. The purpose of this service is to give the possibility to retrieve specific metadata for a set of AOs in order to support various AO browsing scenarios including the presentation of particular AO metadata after a search.

Service input:

Parameter name	Parameter type	Description
AOids	Vector	The AOids of the AOs for which specific metadata elements (those specified by the second parameter) are requested.
lomElements	Vector	An array of LOM elements that should be retrieved for

		each one of the AOs specified in the first parameter.
<i>Service output:</i>		
Parameter name	Parameter type	Description
get_AO_summaryReturn	Vector	An array containing the requested metadata elements for each one of the specified AOs. Each entry in this array is another array (Vector) that contains the AOid of an AO and the values of the LOM elements requested.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.3.4 Alert/Expose

No alert/expose services have been implemented for the Assessment Objects Repository.

5.2.2.4. Courseware Objects Repository services

This section presents the services offered by the Courseware Objects Repository grouped in the categories identified by the IMS DRI specification (Search/Expose, Submit/Store, Request/Deliver and Alert/Expose). Before proceeding with the description of the services it should be noted that the state (EDITING or RENDERED) of COs is represented using the lifecycle/status LOM element. In particular the 'draft' value of this element is used to represent a CO that is in EDITING state while the 'final' value is used to represent a CO that is in RENDERED state.

5.2.2.4.1 Search/Expose

search_CO		
This service is used in order to search for COs satisfying a given Boolean LOM filter. It is a Boolean search service that handles queries which are expressed by Boolean LOM filters specifying the LOM metadata parameters to be examined in order to return a CO. The first parameter of the service is the Boolean LOM filter used in the search and the second parameter is a Boolean flag signifying if the filter should additionally be used for the LOs inside COs. If the flag is false, then only the CO metadata is considered and only COs with LOM metadata matching the filter is returned. If the flag is true, then additional COs are returned: those that have LOs with metadata matching the filter even if the CO LOM metadata do not match the filter.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
booleanLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Boolean LOM filter to be used in order to search for qualifying COs. The structure and semantics of Boolean LOM filters are given in Section 3.4.4.1.
checkLOs	boolean	A Boolean flag. If it is true the filter is applied to LOs and any CO that contains any of the qualifying LOs is also returned by the service.

Service output:

Parameter name	Parameter type	Description
search_COReturn	Vector	An array containing the COids of the COs that satisfy the given filter

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

fuzzy_search_CO

This service is used in order to search for COs satisfying a given Fuzzy LOM filter. The result is a ranked list of the qualifying COs. The first parameter to the service is the LOM fuzzy filter to be applied. The second parameter is a flag signifying if the filter should additionally be used for the LOs inside COs. If the checkLOs flag is false, then only the CO metadata is considered and the ranks are computed by matching the Fuzzy LOM filter with the CO metadata. If the checkLOs flag is true, then the final rank is computed by combining the rank of the CO (as computed using only the CO LOM metadata) and the ranks of the LOs inside the CO (as computed using only the LO LOM metadata).

The formula to combine the ranks is the following:

$$\text{Final rank} = a_1 * r + a_2 * (r_1 + r_2 + \dots + r_n) / n$$

Where a_1 and a_2 are two real values that add to one ($a_1 + a_2 = 1$) representing the relative importance of the rank given to the CO without considering its LOs (r) and the ranks given to its LOs (r_1, r_2, \dots, r_n). The number of LOs inside the CO is n .

Service input:

Parameter name	Parameter type	Description
fuzzyLOMfilter	Document	It corresponds to an xml document that contains the xml representation of the Fuzzy LOM filter to be used in order to search for qualifying COs. The structure and semantics of Fuzzy LOM filters are given in Section 3.4.4.1.
checkLOs	boolean	A Boolean flag. If it is true the filter is also applied to LOs and the final rank for the CO is computed by combining the ranks of the LOs inside a CO and the rank of the CO.
weight	float	This parameter essentially corresponds to parameter a_1 given in the formula above combining the rank of the qualifying CO and the ranks of its LOs. a_2 in the same formula is computed as $a_2 = 1 - \text{weight}$.

Service output:

Parameter name	Parameter type	Description
fuzzy_search_COReturn	Vector	An array containing the <COid,rank> pairs of the COs that satisfy the given filter and the corresponding ranking of each CO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.4.2 Submit/Store

create_CO

This service creates a new CO and gives a new COid to it that is returned by the service. The new CO is set in EDITING state by default. Creating CO involves submission and storage of the CO description (METS document) to the CO repository.

Service input:

Parameter name	Parameter type	Description
incomingDoc	Document	It corresponds to an xml document with the representation of the new AO using METS as described in Chapter 3.

Service output:

Parameter name	Parameter type	Description
create_COReturn	string	A string representing the unique COid given to the newly created CO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

update_CO

This service updates an existing CO. The CO should be in EDITING state in order to be updated. If the CO is in RENDERED state, no update is made and an appropriate error message is returned. Updating a CO involves submission and storage of the new CO description (METS document) to the CO repository.

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO that should be updated.
newDoc	string	It corresponds to an xml document with the representation of the new AO using METS as described in Chapter 3.

Service output:

Parameter name	Parameter type	Description
update_COReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_CO

This service deletes an existing CO. The CO should be in EDITING state in order to be deleted. If the CO is in RENDERED state, no deletion is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO that should be deleted.

Service output:

Parameter name	Parameter type	Description
delete_COReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

render_CO

This service puts an existing CO in RENDERED state. If the CO is already in RENDERED state, no change is made and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO that should be put in RENDERED state.

Service output:

Parameter name	Parameter type	Description
render_COReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

createCopyOfRendered_CO

This service creates a new CO that is a copy of an existing CO in RENDERED state. The new CO is put in EDITING state. Using this service new COs can be created that are based on existing ones and further edited. The unique COid of the newly created CO is returned. If the source CO is not in RENDERED state, no new CO is created and an appropriate error message is returned.

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO in RENDERED state that will be copied.

Service output:

Parameter name	Parameter type	Description
createCopyOfRendered_COReturn	string	This string contains the unique COid given to the newly created CO.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.2.4.3 Request/Deliver

get_CO

This service returns the CO description (METS document) of a specific CO (its COid is given as input to the service).

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO to be retrieved.

Service output:

Parameter name	Parameter type	Description
get_COReturn	string	The METS document in the form of a string that corresponds to the description of the CO requested.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

get_All_LO_in_CO

Get all LOids of the LOs that are contained in a specific CO. The descriptions of these LOs can be later retrieved using the corresponding services of the LO repository.

Service input:

Parameter name	Parameter type	Description
COid	string	The COid of the CO for which the constituent LOs are requested.

Service output:

Parameter name	Parameter type	Description
get_All_LO_in_COReturn	Vector	An array containing the LOids of the LOs that are contained in the CO whose COid is given as an input parameter to the service.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

get_CO_summary

This service retrieves the specified LOM elements (metadata) for particular COs. The purpose of this service is to give the possibility to retrieve specific metadata for a set of COs in order to support various CO browsing scenarios including the presentation of particular CO metadata after a search.

Service input:

Parameter name	Parameter type	Description
COids	Vector	The COids of the COs for which specific metadata elements (those specified by the second parameter) are requested.
lomElements	Vector	An array of LOM elements that should be retrieved for each one of the COs specified in the first parameter.

Service output:

Parameter name	Parameter type	Description
get_CO_summaryReturn	Vector	An array containing the requested metadata elements for each one of the specified COs. Each entry in this array is another array (Vector) that contains the COid of a CO and the values of the LOM elements requested.

Fault:

Parameter name	Parameter type	Description
Code	integer	The error code in case of an error during the execution of the service.
Msg	string	An error message that corresponds to the above error code.

5.2.2.4.4 Alert/Expose

alert_for_CO

This service is used to register an alert for a user interested in finding new COs created or updated that satisfy a specific Boolean LOM filter. To keep the implementation more flexible the notification of the user is to be done through special services that allow for the retrieval of objects satisfying an alert (see service check_alert_for_CO below).

Service input:

Parameter name	Parameter type	Description
booleanLOMfilter	string	The Boolean LOM filter that specifies what kind of COs is requested by the user registering the alert. The structure and semantics of Boolean LOM filters are given in Section 3.4.4.1.
comment	string	A descriptive comment for the alert.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
alert_for_COReturn	string	This string contains the unique alertid that is given to the newly created alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

reuse_alert_for_CO

This service is used to register an existing alert for a specific user. The reason behind this service is that more than one user may be interested in the same alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
reuse_alert_for_COReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

delete_alert_for_CO

Removes the specified alert for the specified user. If the alert has no more users registered, then the alert is removed from the repository.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.

Service output:

Parameter name	Parameter type	Description
delete_alert_for_COReturn	string	A string containing a message that describes if the service has been successfully executed.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

check_alert_for_CO

This service is used to check in the CO repository if COs exist that satisfy the specified alert. This checking could be done in the whole repository, when the checkNewObjects flag is false, or in the set of newly created and updated objects (i.e. the ones created or updated from the previous time the alert was checked for the specified user), when the checkNewObjects flag is true. The service returns the list of COids that satisfy the alert.

Service input:

Parameter name	Parameter type	Description
alertid	string	The alertid of the alert to be registered for the user specified in the second parameter.
userid	string	The userid of the user that registers the alert.
checkNewObjects	boolean	This parameter is a Boolean flag. If its value is 'true' then the service returns only the newly created or updated objects that satisfy the alert. If it is 'false' then all the COs satisfying the alert are returned.
checkLOs	boolean	This parameter is a Boolean flag. If its value is 'true' then the Boolean LOM filter is also applied to LOs so that COs including LOs that satisfy the alert filter are also returned.

Service output:

Parameter name	Parameter type	Description
check_alert_for_COReturn	Vector	An array containing the COids of the COs that satisfy the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_user_alerts_for_CO

Retrieves all the alerts registered for a specific user.

Service input:

Parameter name	Parameter type	Description
userid	string	The userid of the user whose alerts are to be returned.

Service output:

Parameter name	Parameter type	Description
retrieve_user_alerts_for_COReturn	Vector	An array containing the information regarding the alerts registered for the user specified in the parameter of the service. For each alert the service returns the alertid, the corresponding Boolean LOM filter of the alert and the comment of the alert.

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

retrieve_all_alerts_for_CO

Retrieves all the alerts registered in the CO repository.

Service input:

No input parameter.		
<i>Service output:</i>		
Parameter name	Parameter type	Description
retrieve_all_alerts_for_COReturn	Vector	An array containing the information regarding the alerts registered in the CO repository. For each alert the service returns the alertid, the userids of the users that have registered this alert, the corresponding Boolean LOM filter of the alert and the comment of the alert.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.3. Dynamic creation of personalized courseware

LOGOS pays particular attention to the issues related to personalization recognizing that “one size fits all” solutions are no longer enough to satisfy the Learners’ educational needs. For that, the personalization framework proposed in this thesis has been implemented in LOGOS to support pedagogically-sound personalized learning experiences on top of its repositories [Mylonakis, 2008]. The personalization services provided by LOGOS can be exploited either by Learners (directly) or by courseware authors for the semiautomatic creation of courseware.

In order to support personalization in terms of the framework presented, Learner Profiles in LOGOS include among others the previously mentioned important elements representing the learning needs of Learners (e.g. learning goals, previous knowledge, learning style, educational level). Moreover, information about Learner’s devices is included, since LOGOS platform supports cross media delivery of learning experiences. Learner Profiles are stored in a special repository with appropriate services for their access and management (Figure 5.1).

LOs and AOs are represented and described according to the interoperability framework as presented in Section 5.2.1. The LOM metadata that are used for the educational description of LOs, AOs and COs include all needed pedagogical information as proposed in the personalization framework.

The Dynamic Courseware Creation Middleware in LOGOS architecture (Figure 5.1) residing between the LO/AO repositories and the CO repository implements the functionality of the Personalization Component and the Transformation Component presented in the proposed framework. Specifically:

1. It performs dynamic creation of a personalized learning experience in an intermediate format (Personalized Learning Experiences Assembler in Figure 5.4) according to specific learning needs expressed in Learner Profiles and exploiting existing Learning Designs as well as the underlying LOs and AOs residing in the corresponding repositories.
2. It transforms the generated intermediate format of the learning experience to a courseware object (Transformation Component in Figure 5.4) according to the METS-based approach of the interoperability framework presented in Figure 5.3.

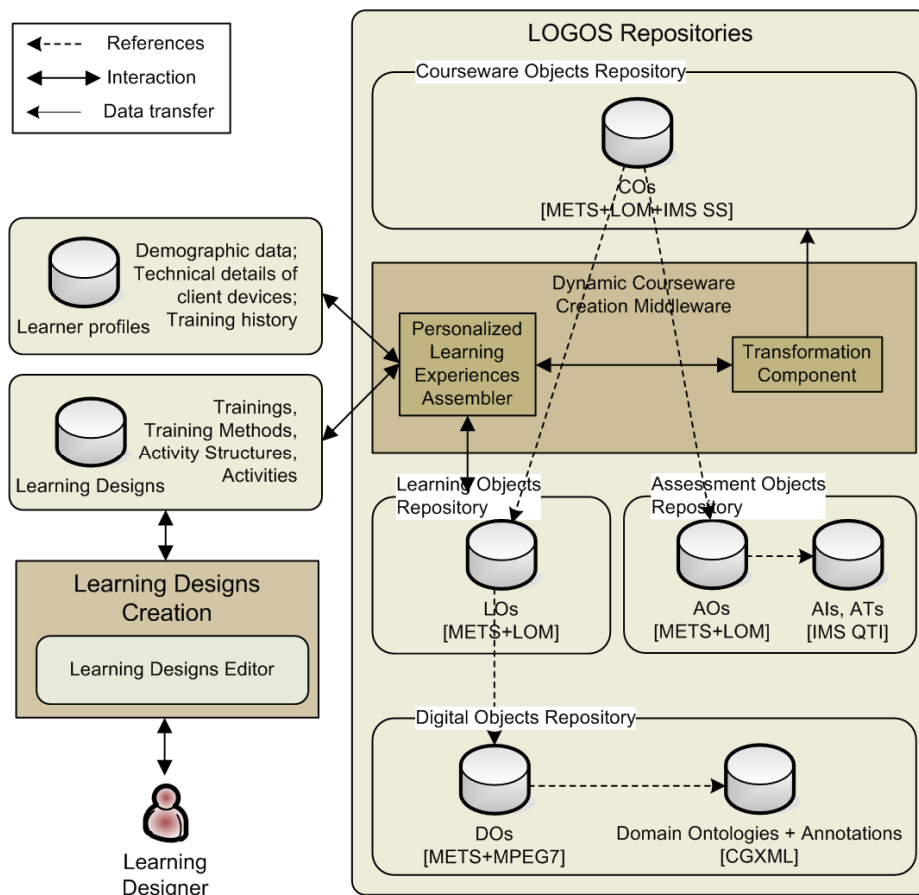


Figure 5.4 LOGOS architecture components related with the dynamic creation of personalized courseware

For the creation and management of Learning Designs as proposed in this framework a special tool has been implemented along with an underlying repository and appropriate web services. This tool named Learning Designs Editor is described in the following section.

5.2.3.1. Creation and Management of Learning Designs - Learning Designs Editor

A special tool has been implemented for the creation of Learning Designs that are based on the instructional model presented in Section 3.4.3 [Theodorakis, 2007]. This tool

named Learning Designs Editor (LDE) provides Learning Design management functionality using an intuitive Graphical User Interface (GUI) so that the creation, maintenance and re-use of Learning Designs can be efficiently supported (Figure 5.5). The constructed Learning Designs are stored in a special repository providing appropriate services for their access and management (Figure 5.6).

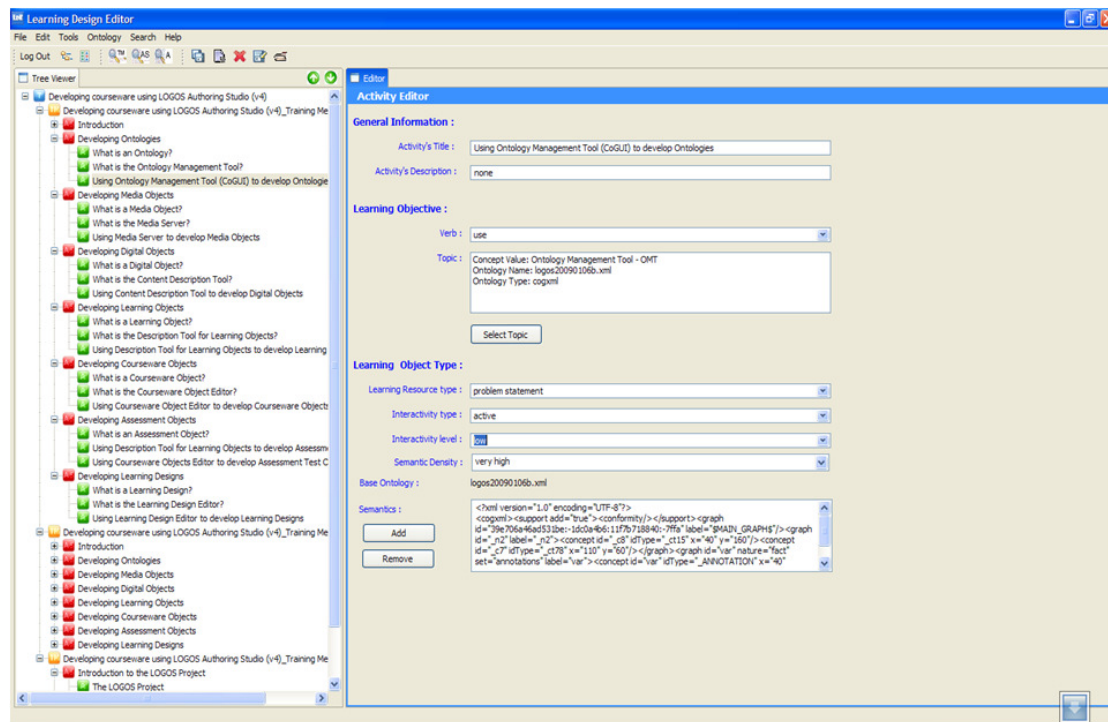


Figure 5.5 The Learning Designs Editor User Interface

Specifically, the architecture for the creation of learning designs is presented consists of the following layers, as illustrated in Figure 5.6:

- The Learning Design Editor (LDE) layer that consists of the following sublayers:
 - The Graphical User Interface. This layer includes the LDE interfaces, the Authentication Tool interfaces, as well as the Profile Manager Interfaces.
 - The Object Model Layer where the Learning Design Model is created through the LDE.
- The Learning Designs Repository (LDR) that consists of the following layers:
 - The Web Services Layer that is used for the remote procedure call that are connected with the underlying levels (Persistent Object Model Layer)
 - The Persistent Object Model Layer that contains the model that is created using the Jena API and the database for the storage of the learning designs.

Learning Design Editor (LDE)

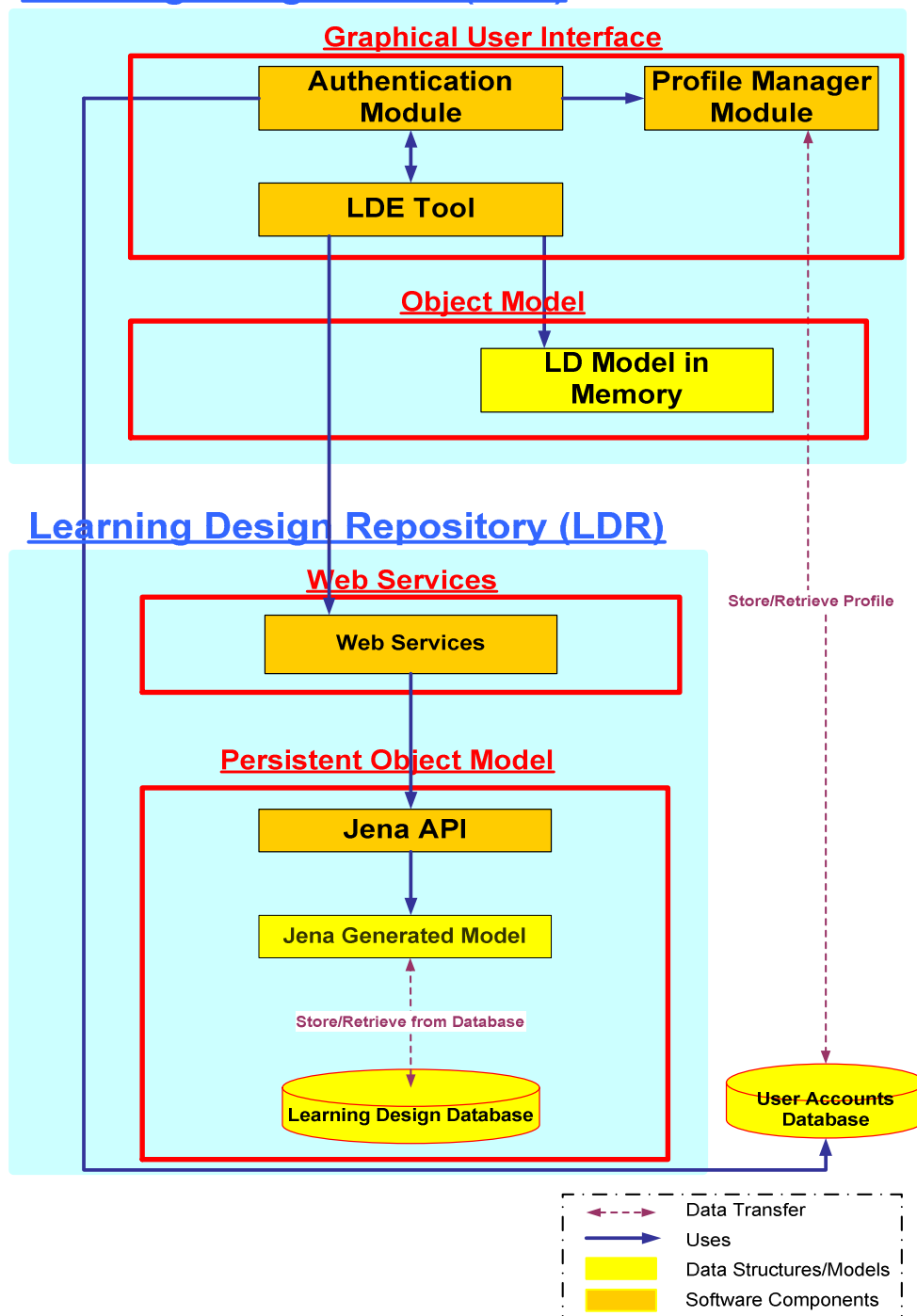


Figure 5.6 Overall architecture of the Learning Designs creation system [Theodorakis, 2007]

More details on the implementation of the Learning Designs Editor (LDE) and its underlying Learning Designs Repository (LDR) can be found in [Theodorakis, 2007].

The Learning Designs Editor provides the following functionality:

- Authorized access so that only users under the Learning Designer role could use the tool and consequently access the Learning Designs Database.

- Browsing, Creation, Viewing and Editing of Trainings. A Training is a collection of TrainingMethods and is considered as container of abstract training scenarios regarding one domain. The different TrainingMethods inside a Training represent alternative ways of creating personalized courseware for the same domain depending on alternative Learning Styles, Educational Levels and Proposed Difficulty of the learners. Each Training could be associated to a number of Learning Objectives.
- Browsing, Creation, Viewing and Editing of Training Methods. Each Training Method is associated to specific Learning Styles and Educational Levels taken from well-defined taxonomies. Each Training Method consists of a sequence of Activity Structures that will be appropriately represented in the tools GUI.
- Browsing, Creation, Viewing and Editing of Activity Structures to be used in one or more Training Methods. Each Activity Structure consists of Activities forming an appropriate structure (sequence or selection).
- Browsing, Creation, Viewing and Editing of Activities. Each Activity contains a preferred Learning Object Types signifying the appropriate types of learning objects that should be found during the automatic construction of personalized courses to implement the Activity.
- Creation and Editing of Learning Object Types to be used in the specification of Activities.
- Creation and Editing of Learning Objectives. Each Learning Objective will be of a specific Learning Objective Type and will contain a Learning Objective Verb, a Learning Objective Topic and a Learning Objective Annotation.
- Wizards to search for Trainings, Activity Structures, and Activities using various parameters according to their properties. The identified Trainings, Activity Structures, and Activities could be further edited, deleted or linked with appropriate elements in the process of their creation.

The creation and editing of Learning Designs is presented in the following activity diagram:

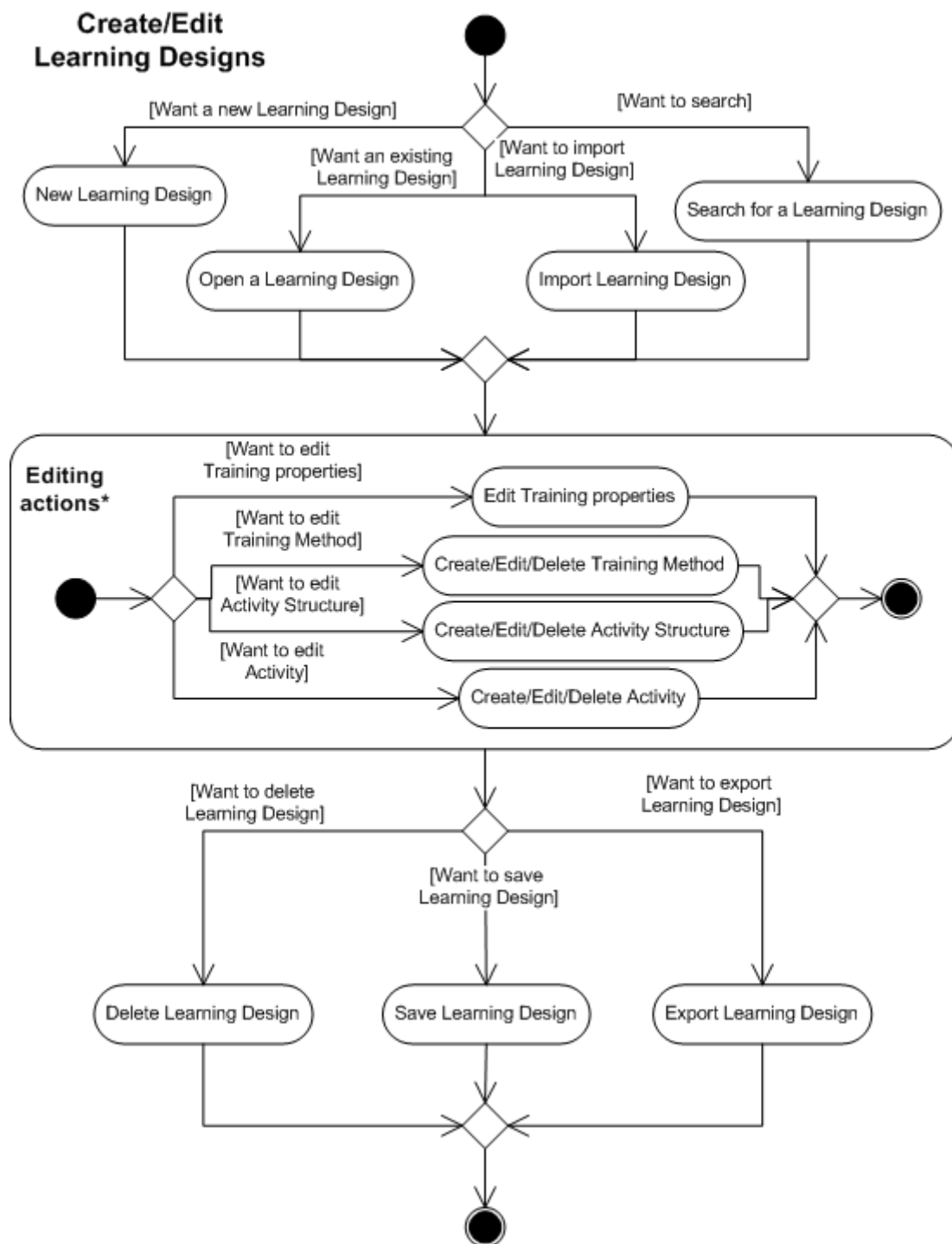


Figure 5.7 Creation and Editing of Learning Designs in LOGOS

The following subsections in more detail the functionality of the Learning Designs Editor.

5.2.3.1.1 User authentication

In order to use the Learning Designs Editor a user has to login first. The login procedure is necessary in order to ensure that only registered users can use the tool. The

authentication process is based on a username and password that have to be given by the user in order to proceed.

If the user is not registered into the system, he has to register first and acquire a new account. The information that the user has to give in order to acquire an account is:

- Desirable user name and password.
- Personal info (first name, last name, email, country, city, address).

After successful login, the user is able:

- To edit his profile (password, personal info).
- To launch the editing interface of the Learning Designs Editor.
- To logout.

5.2.3.1.2 Identifying a Training to edit

There are four complementary ways in order to locate/create a Training for editing. The first option is to request the creation of a new training. In this case the Learning Designs Editor creates an empty Training (only its root node is present) and the user can proceed with the addition of nodes in the tree structure and editing of their properties.

The second option is to open an existing Training. All Trainings are stored in a repository, so when the user selects to open an existing one he receives a list of available Trainings from which he can select and open a specific one. If the Training that is opened does not belong to the user (i.e. it has been created by another user), then it is opened in read-only mode.

The third option is to search for a Training using certain criteria: title, description and planner (i.e. creator of the Training). The user can enter one or more of these criteria and the Trainings that satisfy the given criteria are listed so that the user can select the desired one and open it.

The last option is to import an existing Training that has been previously exported in a file. In that case the user has to locate the file in his file system and load it.

5.2.3.1.3 Editing a Training

Having identified a Training to edit, the user is able to:

- Browse the tree structure of the Training and change it by deleting nodes, inserting new ones or changing the position of certain nodes in the tree.

- Edit the properties of the root node of the Training
- Edit the properties of the Training Methods under the Training node
- Edit the properties of Activity Structures
- Edit the properties of Activities

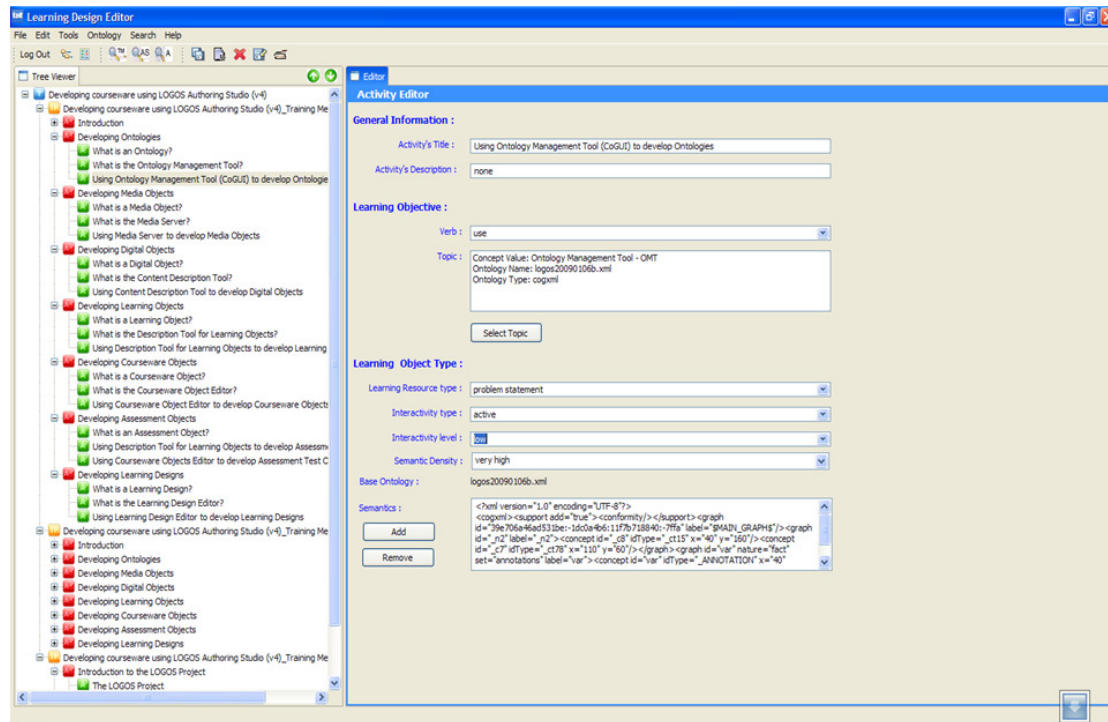


Figure 5.8 The Learning Design Editor offers a tree view of the opened Training (left part) and a property sheet (right part) that is used to present and edit the properties of each tree node shown at the left part

The major editing areas are two:

- A tree representation of the opened Training on the left that shows all the nodes created so far (the root Training node along with the underlying Training Methods, Activity Structures and Activities).
- A property sheet on the right that is used to present and edit the properties of the selected tree node. In order to edit the properties of a certain node, the user has to select it first on the tree view on the left and then use the property sheet to insert/change the values of each property. Each different type of Training nodes has a different property sheet.

(a) *Browsing the Training tree and changing its structure*

There are four complementary ways in order to locate/create a Training for editing. The first option is to request the creation of a new training. In this case the Learning Designs

Editor creates an empty Training (only its root node is present) and the user can proceed with the addition of nodes in the tree structure and editing of their properties.

The tree view of the opened Training offers the possibility to the user to see the structure of the Training in detail. Each node in the tree is shown with a small icon representing its type (Training, Training Method, Activity Structure or Activity) and its title. The user can select any of the tree nodes to see the corresponding properties of the node.

The user is also able to create new tree nodes and in particular:

- To create a new Training Method under the root Training node.
- To create a new Activity Structure under a specific Training Method
- To create a new Activity under a specific Activity Structure.

The user can furthermore copy a Training Method, an Activity Structure or an Activity in the tree and paste it as a new node in another appropriate position.

Moreover the user is able to change the position of a node under its parent node. In particular (s)he can:

- Move up or down an Activity Structure with respect to the sibling nodes under the parent Training Method
- Move up or down an Activity with respect to the sibling nodes under the parent Activity Structure

Finally the user may delete a node from the tree.

All of the above editing actions are given through context-sensitive popup menus on the tree nodes.

(b) Editing the properties of a Training

When the user selects the root Training node, its properties are shown in the property sheet at the right of the Learning Designs Editor window. These properties are the following:

- The title of the Training. This is also presented at the tree structure. The user is able to edit the title through the corresponding text field.
- The textual description of the Training. The user is able to edit the description through the corresponding text field.

- The Learning Objective of the Training. This is a pair of two values, as defined in the instructional ontology: The Learning Objective verb and the Learning Objective topic. The verb can take values from a certain vocabulary and the user is able to change this value by selecting the desired one from a list. The topic can take values from a domain ontology concepts (classes) or individuals. The user is able to browse the concepts and individuals of the selected domain ontology and select the desired one. The selection of a domain ontology in order to be used for the specification of Learning Objectives topics is possible through the ‘Ontology’ menu offered by the Learning Designs Editor.

(c) Editing the properties of a Training Method

When the user selects a Training Method node in the Training tree, its properties are shown in the property sheet at the right of the Learning Designs Editor window. These properties are the following:

- The Difficulty of the Training Method. Its value signifies the Learner difficulty level that the Training Method is appropriate for. The user is able to edit the Difficulty level by selecting a value from a list in the corresponding list box.
- The Educational Level of the Training Method. The value of this property signifies the Learner educational level that the Training Method is appropriate for. The user is able to edit this property by selecting a value from a list in the corresponding list box.
- The Learning Style of the Training Method. The value of this property signifies the Learner preferred Learning Style that the Training Method is appropriate for. The user is able to edit this property by selecting a value from a list in the corresponding list box.

(d) Editing the properties of an Activity Structure

When the user selects an Activity Structure node in the Training tree, its properties are shown in the property sheet at the right of the Learning Designs Editor window. These properties are the following:

- The title of the Activity Structure. This is also presented at the tree structure. The user is able to edit the title through the corresponding text field.
- The type of the Activity Structure (either ‘sequence’ or ‘selection’). The user is able to edit this property by selecting a value from a list in the corresponding list box.

- The Learning Objective of the Activity Structure. This is a pair of two values, as defined in the instructional ontology: The Learning Objective verb and the Learning Objective topic. The verb can take values from a certain vocabulary and the user is able to change this value by selecting the desired one from a list. The topic can take values from a domain ontology concepts (classes) or individuals. The user is able to browse the concepts and individuals of the selected domain ontology and select the desired one. The selection of a domain ontology in order to be used for the specification of Learning Objectives topics is possible through the ‘Ontology’ menu offered by the Learning Designs Editor.

(e) Editing the properties of an Activity

When the user selects an Activity node in the Training tree, its properties are shown in the property sheet at the right of the Learning Designs Editor window. These properties are the following:

- The title of the Activity. This is also presented at the tree structure. The user is able to edit the title through the corresponding text field.
- The textual description of the Activity. The user is able to edit the description through the corresponding text field.
- The Learning Objective of the Activity. This is a pair of two values, as defined in the instructional ontology: The Learning Objective verb and the Learning Objective topic. The verb can take values from a certain vocabulary and the user is able to change this value by selecting the desired one from a list. The topic can take values from a domain ontology concepts (classes) or individuals. The user is able to browse the concepts and individuals of the selected domain ontology and select the desired one. The selection of a domain ontology in order to be used for the specification of Learning Objectives topics is possible through the ‘Ontology’ menu offered by the Learning Designs Editor.
- The Learning Object Type of the Activity. The Learning Object Type consists of the Learning Resource Type, the Interactivity Type, the Interactivity Level, the Semantic Density and the Semantics. The meaning of these elements has been described in detail in Section 3.4.1.2.

5.2.3.1.4 Searching

One important aspect of the functionality supported by the Learning Designs Editor is to find and reuse parts of a Training (i.e. Training Methods, Activity Structure and Activities) in other Trainings. The user may search for parts of a Training, browsing the results returned and selecting an object returned in order to be copied and then pasted in an appropriate place in the currently edited Training.

(a) *Searching for Training Methods*

When the user selects to search for Training Methods (by selecting the corresponding item in the ‘Search’ menu or by clicking on the corresponding button in the main toolbar), a special window opens where the user can provide the searching parameters. These parameters are the following:

- *Title of Training*: the user can provide the title or part of the title of the Training that the Training Method belongs to.
- *Description of Training*: the user can provide the description or part of the description of the training that the Training Method belongs to.
- *Planner of Training*: the user can choose from the list of planners one specific planner to see all Training Methods that belong to his/her Trainings.
- *Difficulty of Training Method*: the user can choose from a list a desired value for the difficulty of the Training Methods he/she searches for.
- *Educational level of Training Method*: the user can define a specific educational level for the Training Methods he/she searches for.
- *Learning Style of Training Method*: the user can define a specific learning style for the Training Methods he/she searches for.

The user may specify all or some of the above parameters and initiate the search. As a result, a list of the qualifying Training Methods is returned. Then, the user can browse the results (see more information about each Training Method) and finally he can copy one of them in order to paste it under the root Training node of the currently edited Training.

(b) *Searching for Activity Structures*

When the user selects to search for Activity Structures (by selecting the corresponding item in the ‘Search’ menu or by clicking on the corresponding button in the main toolbar), a special window opens where the user can provide the searching parameter (only one search parameter is currently supported). The searching parameter is the Title of Activity Structure where the user can provide the title or part of the title of the Activity Structure.

Then the user can initiate the search. As a result, a list of the qualifying Activity Structures is returned. Then, the user can browse the results (see more information about each Activity Structure) and finally he can copy one of them in order to paste it under a Training Method of the currently edited Training.

(c) *Searching for Activities*

When the user selects to search for Activities (by selecting the corresponding item in the ‘Search’ menu or by clicking on the corresponding button in the main toolbar) a special window opens where the user can provide the searching parameters. The search parameters currently supported are the following:

- Title of Activity: the user can provide the title or part of the title of the Activity.
- Description of Activity: the user can provide the description or part of the description of the Activity.

The user may specify all or one of the above parameters and initiate the search. As a result, a list of the qualifying Activities is returned. Then, the user can browse the results (see more information about each Training Method) and finally he can copy one of them in order to paste it under an Activity Structure of the currently edited Training.

5.2.3.1.5 **Saving and exporting a Training**

There are three options of saving a Training. The first option is to save the currently opened Training as a new one. This option is useful when the opened Training belongs to another user (planner). In this case changes are forbidden. However, if the user saves the Training as a new one, the newly created copy of the initial Training belongs to the current user and he may proceed with editions.

The second option is the ordinary saving of the currently edited Training. When this option is selected, the Learning Designs Editor performs a check in the edited Training to see if it is correctly formed. Possible problems may be:

- Incomplete data: Some properties of the Training or its parts (Training Methods, Activity Structures or Activities) do not have values specified.
- Incomplete structure: One or more nodes in the Training tree are missing (e.g. the Training does not have any Training Method or a Training Method does not have any Activity Structure underneath or an Activity Structure does not have any Activities underneath).

The Learning Designs Editor identifies possible problems within the currently edited Training and invites the user to correct them. The user has the possibility to save the Training without correcting it leaving the corrections for later time.

Another option is to export the Training to a file. In that case the user is able to define a password so that the created file can be protected from unauthorized importing from another user.

5.2.3.2. Integration of Personalization functionality in LOGOS Learning Management System

In this section we describe in detail using use cases the integration of the personalization functionality in LOGOS Learning Management System. Moreover, the descriptions of the web services related with the personalization functionality are also presented.

5.2.3.2.1 Use cases

The use cases developed for the integration of the personalization functionality in LOGOS Platform are presented in Figure 5.9.

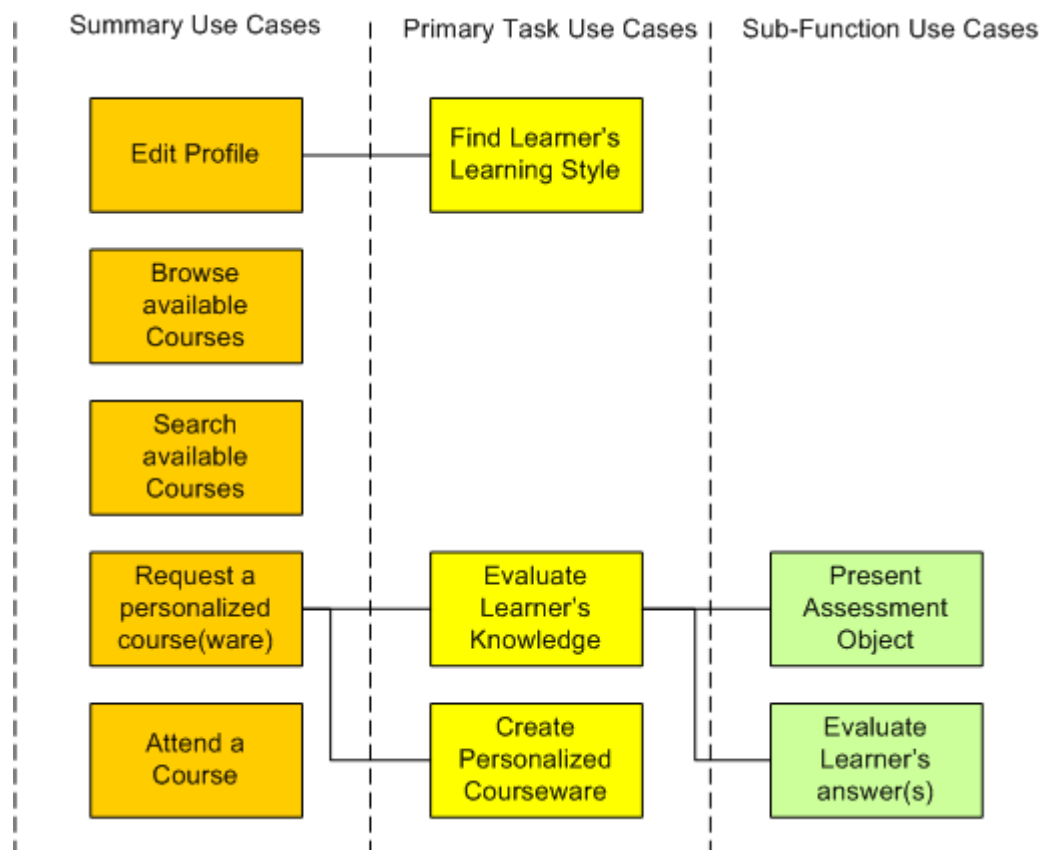


Figure 5.9 Use cases overall scheme

In the following tables the above use cases are described in detail:

USE CASE #	Edit Learner Profile	
Goal in Context	The Learner wants to edit his/her Learner Profile.	
Scope	LMS	
Level	Summary	
Preconditions	Learner should be registered and connected to the LMS.	
Success End Condition	Learner's profile is successfully updated.	
Failed End Condition	Learner could not update his/her profile.	
Primary, Secondary Actors	Learner LMS	
Trigger	The Learner wants to edit his/her Learner Profile.	
DESCRIPTION	Step	Action

	1	The Learner can edit any of the following: Demographic information Learning Style (Learner can use an appropriate questionnaire, depending on the selected Learning Style taxonomy, to help him/her to <i>find his/her Learning Style</i>) Educational Level Other preferences (e.g. language, devices, preferred planner(s), preferred learning provider(s), etc.)
	2	The Learner submits the changes to the LMS
	3	The LMS updates Learner's profile
EXTENSIONS	Step	Branching Action

USE CASE #	Browse available Courses	
Goal in Context	The Learner wants to find a course for his/her needs.	
Scope	LMS	
Level	Summary	
Preconditions	Learner should be registered and connected to the LMS.	
Success End Condition	The Learner is presented with a list of available Courses and (s)he may attend a course.	
Failed End Condition	LMS could not retrieve the available Courses. Connection with the underlying course database failed.	
Primary, Secondary Actors	LMS Learner	
Trigger	The Learner wants to find a course in the LMS for his/her needs.	
DESCRIPTION	Step	Action
	1	The Learner selects a domain from the available ones (e.g. Bulgarian Iconography).
	2	The LMS presents a list of all available courses for this domain.
	3	While the Learner is browsing the available courses, the LMS shows all important information for each course (course metadata and underlying structure?) when it is highlighted.
	4	The Learner can follow any option of the following: <i>Attend a course</i> <i>Search available courses</i> using specific criteria <i>Request a personalized course</i>
EXTENSIONS	Step	Branching Action
	2	2a1) There are no available courses for the selected domain. The Learner can follow any option of the following: <i>Search available courses</i> using specific criteria <i>Request a personalized course</i>

USE CASE #	Search available courses	
Goal in Context	The Learner wants to find a course for his/her needs.	
Scope	LMS	
Level	Summary	
Preconditions	Learner should be registered and connected to the LMS.	
Success End Condition	The Learner is presented with a list of available Courses satisfying his/her criteria and (s)he may attend a course.	
Failed End Condition	Connection with the LMS failed.	

	Connection with the underlying course database failed.	
Primary, Secondary Actors	LMS Learner	
Trigger	The Learner wants to find a course in the LMS for his/her needs.	
DESCRIPTION	Step	Action
	1	The Learner fills in a search form to perform search using specific criteria targeting to courses' metadata. The Learner can select to synchronize the values of some criteria (e.g. learning style, educational level, difficulty etc.) with those already given in his/her profile.
	2	The LMS presents a list with all available courses satisfying the Learner's criteria.
	3	While the Learner is browsing the available courses, the LMS shows all important information for each course (course metadata and underlying structure?) when it is highlighted.
	4	The Learner can follow any option of the following: <u>Attend a course</u> <u>Search available courses</u> again using specific criteria <u>Request a personalized course</u>
EXTENSIONS	Step	Branching Action
	2	2a1) There are no available courses for the specific criteria. The Learner can follow any option of the following: <u>Search available courses</u> again using specific criteria <u>Request a personalized course</u>

USE CASE #	Request a personalized course(ware)	
Goal in Context	The Learner wants to be provided with a personalized course(ware) satisfying his/her special needs and preferences.	
Scope	LMS	
Level	Summary	
Preconditions	Learner should be registered and connected to the LMS.	
Success End Condition	The Learner is provided with a personalized course(ware).	
Failed End Condition	Cannot create a personalized course(ware) for the Learner.	
Primary, Secondary Actors	Learner LMS LD Database COE Courseware Author Personalization Middleware Courseware Objects Repository	
Trigger	The Learner wants a personalized course(ware) in the LMS for his/her needs.	
DESCRIPTION	Step	Action
	1	The Learner selects a domain (e.g. Bulgarian Iconography) from the available ones.
	2	The LMS calls the LD Database in order to search for all Learning Designs that are available for the selected domain.
	3	The LD Database returns an XML file with the id, title, description and planner of all Learning Designs (Trainings) that are related with a specific domain and triples of LS, EL and difficulty that characterize the underlying Training Methods of each LD (see <i>LDsInDomainExample.xml</i> in Appendix 6.3).
	4	The LMS presents a list of the available Learning Designs for the

		domain and the basic info for them.
	5	The Learner browses the available Learning Designs and selects one Training Method that will be used for the dynamic construction of the personalized course.
	6	The LMS asks the Learner if (s)he wants to <i>evaluate his/her knowledge in the specified domain</i> in order to be taken into account in the personalization process.
	7	The LMS prepares an XML document with the parameters that will be taken into account in the personalization process (see <i>InputParameters_middleware.xml</i> in Annex) and pass a request to the COE to <i>create the personalized courseware</i> . Regarding the Learner's goals/objectives, only the records that are related with the selected domain get included in the XML document (e.g. Bulgarian Iconography).
	8	The Learner is informed about the arrival of the personalized courseware (how? from the Course Manager?) and can now <i>attend the course</i> including the generated personalized courseware.
EXTENSIONS	Step	Branching Action
	2	2a1) There are no available LDs for the selected domain. The Learner can select another domain or abort.
	6	Learner's knowledge could not be evaluated. The procedure continues to Step 7.

USE CASE #	Create personalized courseware	
Goal in Context	A request for personalized courseware has arrived in the COE by the LMS to satisfy the Learner's special needs and preferences.	
Scope	COE	
Level	Primary Task	
Preconditions	A request for personalized courseware has arrived by the LMS with the appropriate info (input parameters) needed to initiate the personalization process.	
Success End Condition	A personalized courseware is created and it's corresponding CO id is transmitted to the LMS.	
Failed End Condition	Could not create a personalized courseware.	
Primary, Secondary Actors	Courseware Author COE Personalization Middleware Courseware Objects Repository LMS	
Trigger	A request for personalized courseware has arrived in the COE by the LMS.	
DESCRIPTION	Step	Action
	1	The Courseware Author sees the request (personalization alert) and initiates the personalization procedure through the COE by calling the Personalization Middleware (createPersExperience(XML document) service) in order to initiate the creation of the personalized courseware.
	2	The Personalization Middleware generates the personalized courseware and stores it as a CO to the Courseware Object Repository. The Personalization Middleware returns to the COE the id of the generated CO.
	3	The Courseware Author browses the generated courseware and (s)he makes any change needed.
	4	The Courseware Author through the COE passes the id of the

		generated CO to the LMS.
EXTENSIONS	Step	Branching Action
	2	The Personalization Middleware could not create a personalized courseware (e.g. it could not find appropriate LOs). What does the Courseware Author? (S)he informs the LMS (Course Manager) about this fact or (s)he is waiting until the courseware can be generated?

USE CASE #		Evaluate Learner's knowledge
Goal in Context	Evaluate the Learner's knowledge in the scope defined by a selected Training Method. Can be used both for pre- and post- assessment.	
Scope	LMS	
Level	Primary Task	
Preconditions	Learner is registered and connected to the LMS. Learner has selected a Training Method.	
Success End Condition	The Learner is provided with a dynamically constructed Assessment and his/her knowledge is being evaluated.	
Failed End Condition	Learner's knowledge could not be evaluated. Possible reasons: Could not find appropriate Assessment Objects to evaluate the knowledge of the Learner.	
Primary, Secondary Actors	LMS Learner Service for the dynamic construction of Assessments Assessments Objects Repository LD Database	
Trigger	The Learner wants and (s)he has chosen his/her knowledge on the scope defined of the selected Training Method to be evaluated.	
DESCRIPTION	Step	Action
	1	The LMS calls the service for the dynamic construction of Assessments based on the Training Method selected by the Learner.
	2	The service for the dynamic construction of Assessments prepares an Assessment (essentially a set of appropriate Assessment Objects – Items or Tests) to evaluate all the learning objectives that are connected with the selected Training Method's structure. Specifically, it is trying to find appropriate Assessment Objects (Assessment Tests Objects or Assessment Item Objects) that will be bound to the Activities of the selected Training Method. The type of the selected Assessment for an Activity depends on how broad (high-level) a learning objective is. For example in order to evaluate a learning objective of the type "comprehend Bulgarian Iconography" a simple question (Assessment Item) would not be adequate. Finally, the service returns to the LMS a simple XML file containing only the sequence of the selected Assessment Objects IDs and a <i>type</i> attribute indicating whether an Assessment ID corresponds to an Assessment Test Object or an Assessment Item Object (see <i>DynamicAssessmentExample.xml</i> in Appendix 6.2).
		The following Steps (3-5) are repeated for each Assessment Object ID in the sequence given in the XML file:
	3	The LMS <i>presents Assessment Object</i> to the Learner.
	4	The Learner completes the current Assessment Object and submits his/her answers to the LMS.
	5	The LMS <i>evaluates Learner's answer(s)</i> in current Assessment

		Object and presents the results to the Learner.
EXTENSIONS	Step	Branching Action
	2	Could not find appropriate Assessment Objects to create the Assessment. Abort - Learner's knowledge cannot be evaluated.

USE CASE #	Present Assessment Object	
Goal in Context	The LMS presents the content of an Assessment Object to the Learner.	
Scope	LMS	
Level	Sub-Function	
Preconditions	The ID of the Assessment Object should be included in the list of the selected Assessment Objects given by the service for the dynamic construction of Assessments.	
Success End Condition	The content of the specified Assessment Object is presented to the Learner.	
Failed End Condition	The content of the Assessment Object cannot be presented. Possible reason: Connection with the Assessment Object repository failed.	
Primary, Secondary Actors	LMS Assessment Object Repository	
Trigger	The LMS should present an Assessment Object to the Learner in order to be completed.	
DESCRIPTION	Step	Action
	1	The LMS calls the get_AO(AOid) service of the Assessment Object Repository.
	2	The Assessment Object Repository service returns the description (METS) and the content (QTI) of the Assessment Object.
	3	The LMS presents to the Learner the content of the Assessment.
EXTENSIONS	Step	Branching Action

USE CASE #	Evaluate Learner's answer(s)	
Goal in Context	Evaluate Learner's answer(s) to an Assessment Object and record or update status of the corresponding learning objective.	
Scope	LMS	
Level	Sub-Function	
Preconditions	Learner should have submitted his/her answer(s) on an Assessment Object	
Success End Condition	Learner's answer(s) to an Assessment Object have been evaluated and the status of the corresponding learning objective has been recorded or updated in the Learner Profile.	
Failed End Condition	Learner's answer(s) cannot be evaluated. Learner's Profile cannot be updated.	
Primary, Secondary Actors	LMS Learner Profile Database	
Trigger	Learner has submitted his/her answer(s) on an Assessment Object for evaluation	
DESCRIPTION	Step	Action
	1	The LMS evaluates Learner's answer(s) based on the instructions given in the corresponding QTI description and calculates the score.
	2	The LMS normalizes (if needed) the score of the Learner on the Assessment in [0.0, 1.0] and records or updates the status of

		the corresponding learning objective (those mentioned in the classification part of the ATO or AIO metadata) in the Learner Profile.
	3	The LMS presents the results to the Learner.
EXTENSIONS	Step	Branching Action

5.2.3.2.2 Services

(a) *Service for the dynamic creation of personalized courseware (Personalization Middleware)*

createPersExperience		
The service generates a personalized courseware according to some input parameters describing Learner's needs and preferences and stores it as a CO to the Courseware Object Repository.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
createPersExperience Input	Document	An XML document with the parameters that will be taken into account in the personalization process (see <i>InputParameters_middleware.xml</i> in Appendix 6.1) and pass a request to the COE to <i>create the personalized courseware</i> . Regarding the Learner's goals/objectives, only the records that are related with the selected domain get included in the XML document (e.g. Bulgarian Iconography).
<i>Service output:</i>		
Parameter name	Parameter type	Description
createPersExperience Return	string	The id of the generated CO in the Courseware Object Repository.
<i>Fault:</i>		
Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

(b) *Service for the retrieval of Learning Designs related with a specific domain*

get_All_LD_in_Domain		
Returns an XML file with the id, title, description and planner of all Learning Designs (Trainings) that are related with a specific domain and triples LS, EL and difficulty in order for the Learner to know the characteristics of the LD underlying Training Methods.		
<i>Service input:</i>		
Parameter name	Parameter type	Description
ontologyFilename	String	The corresponding ontology file name for a domain (e.g. for Bulgarian Iconography)

Service output:

Parameter name	Parameter type	Description
get_All_LD_in_DomainReturn	string	An XML document in the form of a string with the ids, titles, descriptions and planners of all Learning Designs (Trainings) that are related with a specific domain and triples LS, EL and difficulty in order for the Learner to know the characteristics of the LD underlying Training Methods (see <i>LDsInDomainExample.xml</i> in Appendix 6.3).

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

*(c) Service for the dynamic creation of Assessments***createDynAssessment**

The service for the dynamic construction of Assessments prepares an Assessment (essentially a set of appropriate Assessment Objects – Items or Tests) to evaluate all the learning objectives that are connected with the selected Training Method's structure. Specifically, it is trying to find appropriate Assessment Objects (Assessment Tests Objects or Assessment Item Objects) that will be bound to the Activities of the selected Training Method. The type of the selected Assessment for an Activity depends on how broad (high-level) a learning objective is. For example in order to evaluate a learning objective of the type "comprehend Bulgarian Iconography" a simple question (Assessment Item) would not be adequate.

Service input:

Parameter name	Parameter type	Description
LDId	string	The id of the Learning Design that the Learner has selected.
TMId	string	The id of the Training Method that the Learner has selected.
inputparam	Document	An XML document with the input parameters that may be taken into account in the dynamic creation of the Assessment
flag	Boolean	A flag indicating if the Learner wants his/her knowledge that is already recorded in his/her profile to be re-evaluated (flag=1) or not (flag=0).

Service output:

Parameter name	Parameter type	Description
createDynAssessment Return	Document	A simple XML file containing the sequence of the selected Assessment Objects IDs and a <i>type</i> attribute indicating whether an Assessment ID corresponds to an Assessment Test Object or an Assessment Item Object (see <i>DynamicAssessmentExample.xml</i> in Appendix 6.2)

Fault:

Parameter name	Parameter type	Description
code	integer	The error code in case of an error during the execution of the service.
msg	string	An error message that corresponds to the above error code.

5.2.3.3. Transformation of generated learning experience intermediate format to Courseware Object - Transformation Component

As mentioned in Section 3.4.5, the intermediate format of the learning experience generated as a result of the personalization process described in the previous section is transformed to an appropriate format (through the Transformation Component) and delivered to the Learner. This could be a SCORM Package, a METS-based representation of a learning experience, etc. In the case of LOGOS the generated learning experience is transformed to a Courseware Object – CO according to the METS-based representation presented earlier in this chapter. This flexible representation of the learning experience in the form of CO allows for the delivery of the learning experience to different channels, after its transformation to the format that the target channel supports. For example, if the learning experience is going to be delivered to the Learner through a PC, then the standard way is to use a SCORM compliant LMS. In this case the CO will be transformed to a SCORM package before delivering it to the LMS.

In this section the transformation of the generated learning experience intermediate format to the METS-based representation of CO will be described. The transformation process is presented in Figure 5.10. The final structure of the learning experience is represented in the *structMap* section of METS. Each activity of this structure corresponds to a *div* element in METS. Each leaf activity points to a LO referenced in the *fileSec* of METS. Finally, appropriate LOM metadata are generated and referenced by the *dmdSec* of METS.

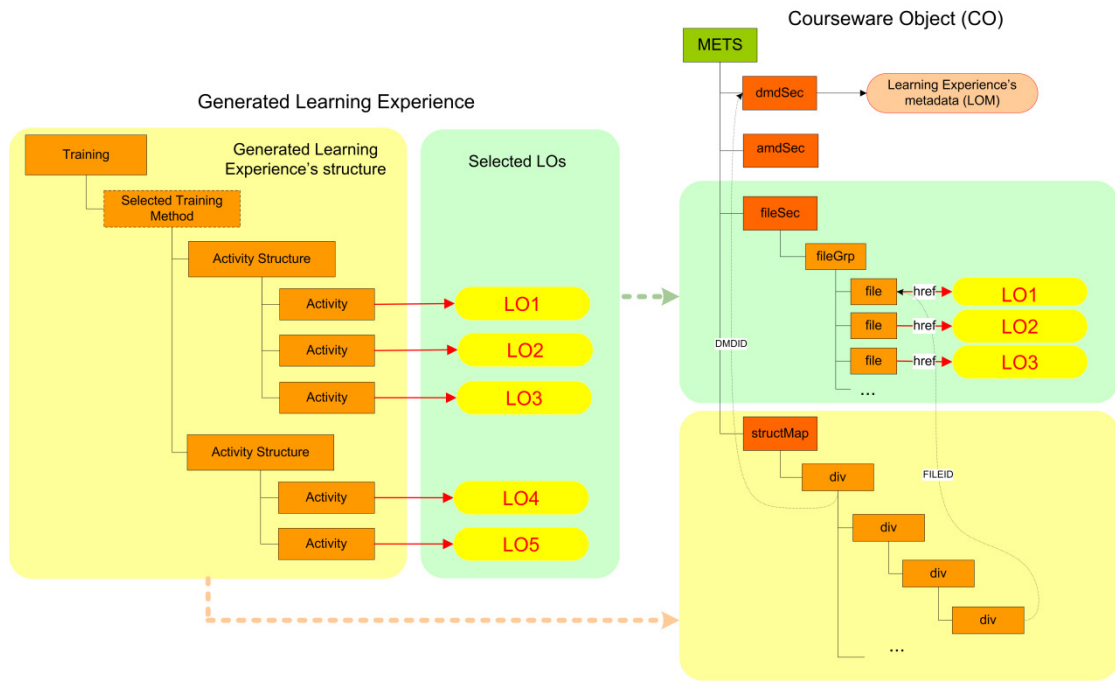


Figure 5.10 Mapping of the generated learning experience intermediate format to Courseware Object (CO)

5.2.4. Transformation of courseware objects to SCORM packages for delivery to LMS

In order to be able for a learning experience to be delivered to a Learning Management System, it should be transformed to SCORM. In the following section, the mapping of the METS-based representation of a courseware object to SCORM package is described, as well as the implementation of the transformation process.

5.2.4.1. Mapping of the METS-based representation of a learning experience (courseware object) to SCORM

Each SCORM package includes an XML document, the manifest file, which describes the structure of a learning experience, as well as its resources. The structure of the learning experience is represented in the *organizations* element that consists of *organization* elements that can be used as many times as needed in case of alternative organizations of the same learning experience. In this case, the attribute *default* is used to indicate the default organization, that is, the organization that will be presented first by the LMS in case that no other instruction is given. Each *organization* is essentially an organization of learning activities that is described with a *title*. The structure of the learning activities within the *organization* element is represented with a hierarchy of *item* elements. Each *item* has a *title* and it is a recursive element that can also include other *item* elements (container item). Each item that is a leaf in this hierarchy corresponds to a single learning activity that is supported by a learning resource (*resource*).

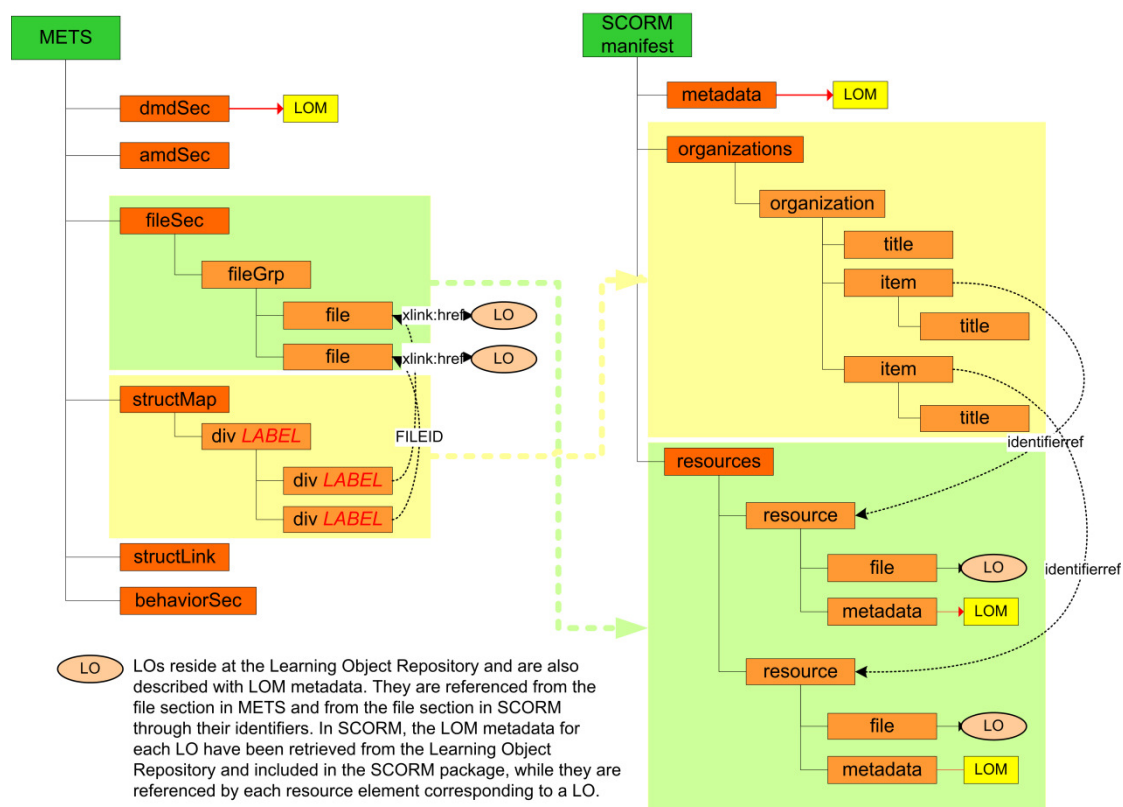


Figure 5.11 Mapping of the METS-based representation of a learning experience (courseware object) to SCORM

According to the above, the *structMap* section of the METS-based representation of a courseware object can be mapped to the *organization* section of the manifest file as illustrated in Figure 5.11 and described in detail in Table 5.2.

Table 5.2 Mapping of structMap section of METS-based courseware object representation to the organization section of SCORM manifest file

METS	SCORM Manifest
structMap	organizations/organization
structMap/ div/@ID	organizations/@default
structMap/ div/@ID	organizations/organization/@identifier
structMap/div/@LABEL	organizations/organization/title
structMap/div/div/@LABEL	organizations /organization/item/item/@identifier
structMap/div/div/@LABEL	organizations /organization/item/item/title
structMap/div/fptr/@FILEID	organizations /organization/item/item/@identifierref

Consider for example the structMap section of a CO as presented in Table 5.3.

Table 5.3 Example of the structMap section of a CO

```
<structMap>
  <div TYPE="coursewareobject" ID="CO109759799438196" LABEL="Bansko-
  Razlog School of Art (vM3)" DMDID="LOM">
    <div ID="ActStrf5d99464-534c-11dd-9c74-b97ce6738348"
    LABEL="Famous themes painted by iconographers from Bansko-Razlog
    iconographic school" TYPE="activity">
      <div TYPE="activity" ID="Activity_f62f558a-534c-11dd-9c74-
      b97ce6738348" LABEL="Famous iconographic characters painted by iconographers
```



```

from Bansko-Razlog iconographic school">
    <div ID="LO0_PC_DIV" TYPE="channel" DMDID="CHANNEL_1">
        <div ID="LO0_PC" TYPE="learningobject">
            <fptr FILEID="LO0_ref" />
        </div>
    </div>
</div>
<div ID="LO0_TV_DIV" TYPE="channel" DMDID="CHANNEL_2">
    <div ID="LO0_TV" TYPE="learningobject">
        <fptr FILEID="LO0_ref" />
    </div>
</div>
<div ID="LO0_MB_DIV" TYPE="channel" DMDID="CHANNEL_3">
    <div ID="LO0_MOBILE" TYPE="learningobject">
        <fptr FILEID="LO0_ref" />
    </div>
</div>
</div>
<div TYPE="activity" ID="Activity_f636817b-534c-11dd-9c74-
b97ce6738348" LABEL="Famous iconographic scenes painted by iconographers
from Bansko-Razlog iconographic school">
    <div ID="LO1_PC_DIV" TYPE="channel" DMDID="CHANNEL_1">
        <div ID="LO1_PC" TYPE="learningobject">
            <fptr FILEID="LO1_ref" />
        </div>
    </div>
<div ID="LO1_TV_DIV" TYPE="channel" DMDID="CHANNEL_2">
    <div ID="LO1_TV" TYPE="learningobject">
        <fptr FILEID="LO1_ref" />
    </div>
</div>
<div ID="LO1_MB_DIV" TYPE="channel" DMDID="CHANNEL_3">
    <div ID="LO1_MOBILE" TYPE="learningobject">
        <fptr FILEID="LO1_ref" />
    </div>
</div>
</div>
</div>
<div ID="ActStrf61eb3b8-534c-11dd-9c74-b97ce6738348"
LABEL="Comparative presentation of specific themes painted by Bansko-Razlog
iconographic school members and other schools" TYPE="activity">
    <div TYPE="activity" ID="Activity_f66d48ef-534c-11dd-9c74-
b97ce6738348" LABEL="Saint Nicholas character painted by iconographers from
Bansko-Razlog iconographic school and other famous iconographic schools">
        <div ID="LO2_PC_DIV" TYPE="channel" DMDID="CHANNEL_1">
            <div ID="LO2_PC" TYPE="learningobject">
                <fptr FILEID="LO2_ref" />
            </div>
        </div>
<div ID="LO2_TV_DIV" TYPE="channel" DMDID="CHANNEL_2">
        <div ID="LO2_TV" TYPE="learningobject">
            <fptr FILEID="LO2_ref" />
        </div>
    </div>
<div ID="LO2_MB_DIV" TYPE="channel" DMDID="CHANNEL_3">
        <div ID="LO2_MOBILE" TYPE="learningobject">
            <fptr FILEID="LO2_ref" />
        </div>
    </div>
</div>
</div>

```

```

        <div TYPE="activity" ID="Activity_f6722af0-534c-11dd-9c74-
b97ce6738348" LABEL="The Nativity of Christ scene painted by iconographers
from Bansko-Razlog iconographic school and other famous iconographic
schools">

            <div ID="LO3_PC_DIV" TYPE="channel" DMDID="CHANNEL_1">
                <div ID="LO3_PC" TYPE="learningobject">
                    <fptr FILEID="LO3_ref" />
                </div>
            </div>
            <div ID="LO3_TV_DIV" TYPE="channel" DMDID="CHANNEL_2">
                <div ID="LO3_TV" TYPE="learningobject">
                    <fptr FILEID="LO3_ref" />
                </div>
            </div>
            <div ID="LO3_MB_DIV" TYPE="channel" DMDID="CHANNEL_3">
                <div ID="LO3_MOBILE" TYPE="learningobject">
                    <fptr FILEID="LO3_ref" />
                </div>
            </div>
        </div>
    </div>
</structMap>
</mets>

```

The result of the transformation of the *structMap* section presented in Table 5.3 to the *organizations* section of the manifest file is given in Table 5.4.

Table 5.4 The organization section of the manifest file resulted from the transformation of the *structMap* section of the intermediate representation that was presented in Table 5.3

```

<organizations default="C0132357293069929">
    <organization identifier="C0132357293069929"
structure="hierarchical">
        <title>Bansko-Razlog School of Art (vM3)</title>
        <item identifier="ActStrf5d99464-534c-11dd-9c74-b97ce6738348">
            <title>Famous themes painted by iconographers from Bansko-
Razlog iconographic school</title>
            <item identifier="Activity_f62f558a-534c-11dd-9c74-
b97ce6738348" identifierref="LO0_ref">
                <title>Famous iconographic characters painted by
iconographers from Bansko-Razlog iconographic school</title>
            </item>
            <item identifier="Activity_f636817b-534c-11dd-9c74-
b97ce6738348" identifierref="LO1_ref">
                <title>Famous iconographic scenes painted by
iconographers from Bansko-Razlog iconographic school</title>
            </item>
            <item identifier="ActStrf61eb3b8-534c-11dd-9c74-b97ce6738348">
                <title>Comparative presentation of specific themes painted
by Bansko-Razlog iconographic school members and other schools</title>
                <item identifier="Activity_f66d48ef-534c-11dd-9c74-
b97ce6738348" identifierref="LO2_ref">
                    <title>Saint Nicholas character painted by iconographers
from Bansko-Razlog iconographic school and other famous iconographic
schools</title>
                </item>
                <item identifier="Activity_f6722af0-534c-11dd-9c74-

```

```

b97ce6738348" identifierref="LO3_ref">
    <title>The Nativity of Christ scene painted by
    iconographers from Bansko-Razlog iconographic school and other famous
    iconographic schools</title>
    </item>
  </item>
</organization>
</organizations>

```

The learning resources of a learning experience and their description are included in the *resources* element, where each learning resource is described with a separate *resource* element. As already mentioned in Chapter 1, a resource could be an Asset (e.g. a simple file, as an image) or a minimum independent unit of instruction (SCO) that consists of a set of Assets and among them a launchable Asset that is used by the SCORM Run-Time Environment to communicate with the LMS. Each SCO *resource* indicates its launchable Asset (html page) through the *href* attribute, while its metadata are referenced through the *adlcp:location* element under the *metadata* element. For the connection of the learning activities represented with leaf *items* with their associated learning resources, the attribute *identifierref* of leaf *items* is used that points to the identifier of the corresponding *resource identifier*.

Table 5.5 Mapping between fileSec section of METS with resources section of SCORM manifest file

METS	SCORM Manifest
fileSec	resources
fileSec/fileGrp/file	resources/resource
fileSec/fileGrp/file/@ID	resources/resource/@identifier

The concept of LO in LOGOS is fully aligned with the concept of SCO since a LO comprises a minimum independent unit of instruction described with LOM metadata. Hence, each file element in the fileSec of METS that points to a LO can be mapped to a SCO resource in SCORM (Table 5.5). This SCO will consist of Assets that correspond to the DOs of the LO and it will also include a launchable Asset. This launchable Asset is an html page including appropriate scripts for the communication of this SCO with the LMS and managing the presentation of the instructional unit contents.

Consider for example the fileSec of a CO presented in Table 5.6.

Table 5.6 Example of the fileSec section of a CO

```

<fileSec>
  <fileGrp>
    <file ID="LO0_ref">
      <FLocat LOCTYPE="URN" xlink:href="0cbc61c7-e6ba-11dc-8f32-df8fa0c9409a"/>
    </file>
    <file ID="LO1_ref">
      <FLocat LOCTYPE="URN" xlink:href="ff31bcd6-e6b9-11dc-8f32-df8fa0c9409a"/>
    </file>
    <file ID="LO2_ref">
      <FLocat LOCTYPE="URN" xlink:href="164358c8-e6ba-11dc-8f32-df8fa0c9409a"/>
    </file>
  </fileGrp>
</fileSec>

```

```

    <file ID="LO3_ref">
      <FLocat LOCTYPE="URN" xlink:href="a22373ca-e6ba-11dc-8f32-
df8fa0c9409a"/>
    </file>
  </fileGrp>
</fileSec>

```

In Table 5.7 the *resources* section is presented as a result of the transformation of the *fileSec* section of the learning experience intermediate format that was given in Table 5.6. The first *resource* element in the following example corresponds to an Asset that includes some common files used in all SCOs launchable Assets (e.g. scripts, files related with the presentation of the content etc.). The other resource elements are SCOs corresponding to LOs. Each DO of a LO is referred with a file element in the resource, while there is also a *dependency* element that allows for the reuse of the previously described common Asset by all SCOs' launchable Assets.

Table 5.7 The resources section of the manifest file resulted from the transformation of the fileSec section of the intermediate representation that was presented in Table 5.6

```

<resources>
  <resource xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
identifier="RES-F87901C5-6B8C-429A-438E-6126880B56A5" adlcp:scormType="asset"
type="webcontent">
    <file href="SharedFiles/css/snstyle.css" />
    <file href="SharedFiles/images/bottom.gif" />
    <file href="SharedFiles/images/next.gif" />
    <file href="SharedFiles/images/next_rollover.gif" />
    <file href="SharedFiles/images/previous.gif" />
    <file href="SharedFiles/images/previous_rollover.gif" />
    <file href="SharedFiles/scripts/APIWrapper.js" />
    <file href="SharedFiles/scripts/courseFunctions.js" />
  </resource>
  <resource xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
adlcp:scormType="sco" identifier="LO0_ref" type="webcontent"
href="resources/f18cd925-e6b9-11dc-8f32-df8fa0c9409a.html">
    <metadata>
      <adlcp:location>lomfiles/f18cd925-e6b9-11dc-8f32-
df8fa0c9409a.xml</adlcp:location>
    </metadata>
    <file href="resources/f18cd925-e6b9-11dc-8f32-df8fa0c9409a.html" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=784" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=780" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=790" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=822" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=844" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=931" />
    <dependency identifierref="RES-F87901C5-6B8C-429A-438E-6126880B56A5" />
  </resource>
  <resource xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
adlcp:scormType="sco" identifier="LO1_ref" type="webcontent"

```

```

href="resources/ff31bcd6-e6b9-11dc-8f32-df8fa0c9409a.html">
  <metadata>
    <adlcp:location>lomfiles/ff31bcd6-e6b9-11dc-8f32-
df8fa0c9409a.xml</adlcp:location>
  </metadata>
  <file href="resources/ff31bcd6-e6b9-11dc-8f32-df8fa0c9409a.html" />
  <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=798" />
  <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=826" />
  <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=828" />
  <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=812" />
    <dependency identifierref="RES-F87901C5-6B8C-429A-438E-6126880B56A5" />
  </resource>
  <resource xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
adlcp:scormType="sco" identifier="LO2_ref" type="webcontent"
href="resources/4fe94d2f-5358-11dd-9c74-b97ce6738348.html">
    <metadata>
      <adlcp:location>lomfiles/4fe94d2f-5358-11dd-9c74-
b97ce6738348.xml</adlcp:location>
    </metadata>
    <file href="resources/4fe94d2f-5358-11dd-9c74-b97ce6738348.html" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=824" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=905" />
    <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=925" />
      <dependency identifierref="RES-F87901C5-6B8C-429A-438E-6126880B56A5" />
    </resource>
    <resource xmlns:adlcp="http://www.adlnet.org/xsd/adlcp_v1p3"
adlcp:scormType="sco" identifier="LO3_ref" type="webcontent"
href="resources/e041d0f0-5358-11dd-9c74-b97ce6738348.html">
      <metadata>
        <adlcp:location>lomfiles/e041d0f0-5358-11dd-9c74-
b97ce6738348.xml</adlcp:location>
      </metadata>
      <file href="resources/e041d0f0-5358-11dd-9c74-b97ce6738348.html" />
      <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=796" />
      <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=896" />
      <file
href="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=873" />
        <dependency identifierref="RES-F87901C5-6B8C-429A-438E-6126880B56A5" />
      </resource>
    </resources>

```

5.2.4.2. Process of transformation of METS-based representation of a learning experience (courseware object) to a SCORM package

For the transformation of the METS-based representation of a learning experience (courseware object) to a SCORM package, software has been implemented [Mylonakis, 2008] that performs this transformation according to the process presented in this

section. This software has been implemented in Java, using also other technologies for XML documents management as XQuery and XSLT.

The process of transformation of METS-based representation of a learning experience (courseware object) to a SCORM package includes four main steps, as illustrated in Figure 5.12:

1. Creation of metadata of the final learning experience in SCORM (*metadata* section of manifest file)
2. Creation of the structure of the final learning experience in SCORM (*organizations* section of manifest file)
3. Creation of the learning experience's resources and their metadata in SCORM (*resources* section of manifest file)
4. Creation of the final SCORM Package (Package Interchange File - PIF)

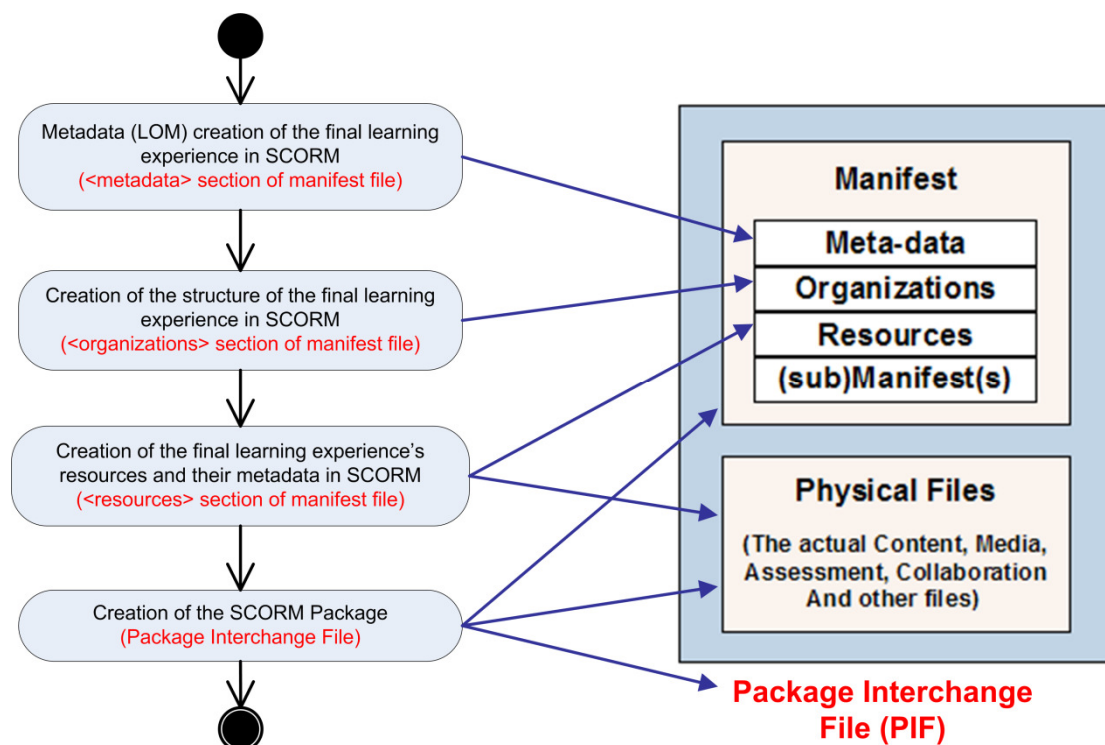


Figure 5.12 Overall process of generation of a SCORM package from a courseware object

In the first step, the LOM metadata of the courseware object are retrieved from its METS representation and saved as a separate file in the SCORM package, while the corresponding metadata section is created in manifest which references the newly created file containing the metadata describing the learning experience as a whole (Figure 5.13).

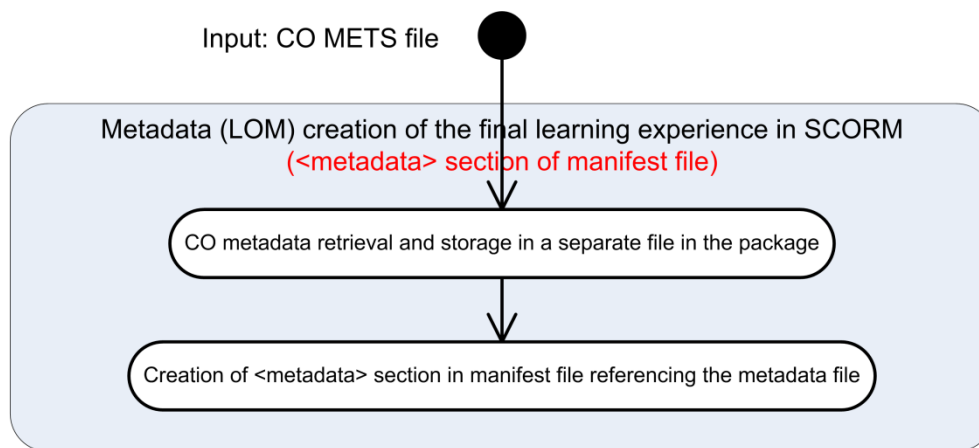


Figure 5.13 Creation of metadata of the final learning experience in SCORM (metadata section of manifest file)

Thereafter, the *structMap* section of METS is transformed to the *organizations* section of SCORM manifest, while in parallel the resources element of the manifest file is being created. This is a complicated procedure illustrated in Figure 5.14.

For each *div* in the *structMap* section of METS a corresponding *item* is created in the manifest file, and the *LABEL* and *ID* of the *div* are transformed to the *title* and *identifier* of the item.

Each *file* element in the *fileSec* of METS that points to a LO residing in the Learning Object Repository is transformed to a SCO resource in SCORM. This SCO will consist of Assets that correspond to the DOs of the LO and it will also include a launchable Asset. Specifically, for each *file* in METS, the corresponding LO is retrieved from the Learning Object Repository and its LOM metadata get stored in a separate file in the SCORM package, while the corresponding *resource* and *metadata* section are created in manifest, which reference the newly created file containing the metadata describing the LO. From the METS representation of each LO, the identifiers of its underlying DOs or the free text that reside in the *fileSec* section are retrieved. For each DO in the LO, its description is retrieved from the Digital Object Repository, from which the location (MediaURI) of its raw content residing at the Media Server is obtained. For each DO that is used in a LO, a corresponding *file* element is created under the LO *resource* element in manifest, pointing to the location of the DO.

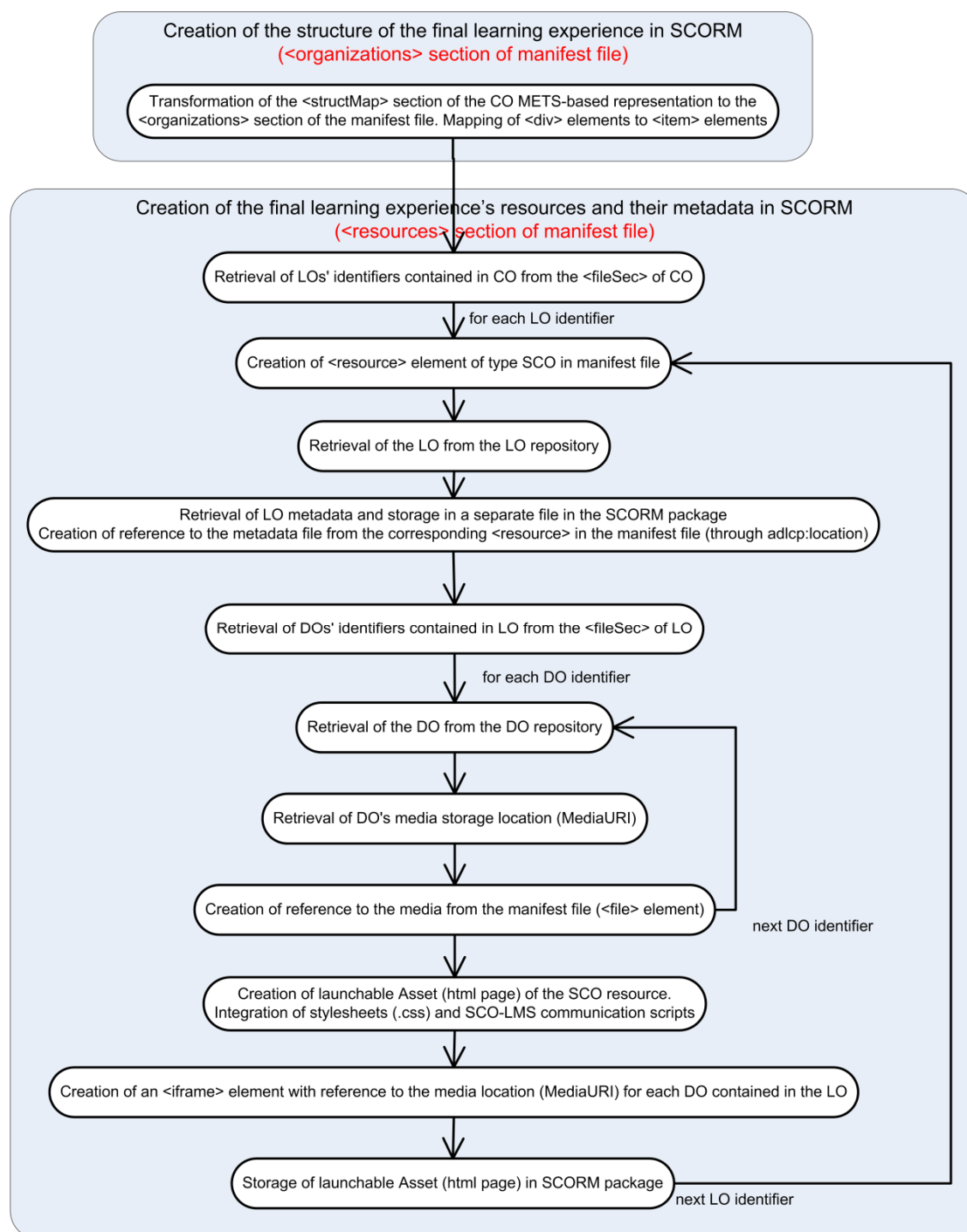


Figure 5.14 Creation of the structure of the final learning experience (organizations section of manifest file) and the learning experience's resources and their metadata (resources section of manifest file)

Finally, for each LO represented with a SCO in manifest, a launchable Asset is constructed in form of an html page, including appropriate scripts for the communication of this SCO with the LMS and managing the presentation of the instructional unit contents. This html page includes references to the locations of the LO's underlying DOs and free text and get stored in the SCORM package after its creation (Table 5.8). A corresponding *file* element is created under the LO *resource* element in manifest, pointing to the location of the html page inside the SCORM package. A

dependency element is also created under each SCO resource that refers to an asset resource containing some common files related with the communication and the presentation of SCOs (communication scripts, stylesheets etc.) and is used by all SCOs launchable Assets (html pages).

Table 5.8 Example of the code of the generated html page corresponding to a SCO's launchable Asset

```
<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html>
  <head>
    <title>Saint Nicholas character painted by iconographers from Bansko-
Razlog iconographic school and other famous iconographic schools
(vM3)</title>
    <meta http-equiv="Content-Type" content="text/html; charset=utf-8"/>
    <script type="text/javascript"
src="../../SharedFiles/scripts/APIWrapper.js"></script>
    <script type="text/javascript"
src="../../SharedFiles/scripts/courseFunctions.js"></script>
    <style type="text/css" media="all"> @import
"../../SharedFiles/css/snstyle.css"; </style>
  </head>
  <body onload="javascript:Initialize();"
onunload="javascript:Terminate();">
    <div class="container">
      <div class="header">
      </div>
      <div class="navigation">
        <div id="previousBtn">
          <a href="javascript:PreviousPage();"></a>
        </div>
        <div id="nextBtn">
          <a href="javascript:NextPage();"></a>
        </div>
      </div>
      <div class="page" style="visibility: visible" id="p0">
        <div class="content">
          <p>Saint Nicholas of Myra is a Bishop of Myra in Lycia (a Greek-
speaking Roman Province). In his lifetime he was known as one opposing the
paganism and the Arianism. After his death he was venerated as a saint and a
patron of the mariners, the tradesmen and the prisoners. At a Middle Age
time his relics were stolen by Italian sailors from the temple in Myra and
were translated to Bari, Italy, where they have been kept until now.</p>
        </div>
        <div class="instructions">
        </div>
      </div>
      <div class="page" id="p1">
        <div class="content">
          <p>Iconographic type: Saint Nicholas is depicted as an elderly man
with a short, full white beard and balding head, telling Holy, holy, holy is
the Lord Almighty. The traditional depiction of Saint Nicholas (whether
half-length or full size) is one of an Orthodox bishop, wearing an
omophorion, sometimes an Eastern Orthodox mitre, sometimes bareheaded. He is
holding a Gospel Book (open or closed) in his left hand while blessing with
his right hand. The image of Saint Nicholas is part of the following scenes:
The Nativity of Saint Nicholas, The Baptism of Saint Nicholas, Saint
```

Nicholas rescuing three virgins from fornication, The saint tonsured as a deacon, Saint Nicholas destroying idols, Saint Nicholas defeating Arius, The saint put in a jail, Saint Nicholas receiving a gift from God, Saint Nicholas endows king Stefan with eyes, etc.</p>

</div>

<div class="instructions">

</div>

</div>

<div class="page" id="p2">

<div class="content">

<p>A demonstration of four half-length depictions of Saint Nicholas from different iconographic schools follows. The present selection brings out the artistic individuality and the pictorial qualities of various schools when presenting the same canonical image in terms of figure, visage and ornaments.</p>

</div>

<div class="instructions">

</div>

</div>

<div class="page" id="p3">

<div class="content">

<iframe

src="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=824" width="800" height="100%">

Hmm, you are using a very old browser.Click here to go directly to included content.

</iframe>

</div>

<div class="instructions">

</div>

</div>

<div class="page" id="p4">

<div class="content">

<iframe

src="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=905" width="800" height="100%">

Hmm, you are using a very old browser.Click here to go directly to included content.

</iframe>

</div>

<div class="instructions">

</div>

</div>

<div class="page" id="p5">

<div class="content">

<iframe

src="http://212.92.2.161/mediaserver/getfile.php?type=document&fid=925" width="800" height="100%">

Hmm, you are using a very old browser.Click here to go directly to included content.

</iframe>

</div>

<div class="instructions">

```

    </div>
  </div>
  <div class="page" id="p6">
    <div class="content">
      <p>The image of Saint Nicholas by Bansko iconographic school is a
      traditional half-length depiction on a dark blue background. The saint is
      dressed in garments of the high clergy. He is holding a closed book in one
      hand and is blessing with the other. The image is realistic and has a strong
      effect on the spectators with its ascetic air and severity. The stylish
      depiction of the garments with no surplus details is impressive. The graphic
      image, the coloring and the manner reveal the hand of an experienced
      artist</p>
    </div>
    <div class="instructions">
    </div>
  </div>
  <div class="page" id="p7">
    <div class="content">
      <p>The image of Saint Nicholas by Strandja iconographic school. The
      depiction of the head with the exclusively elegant and delicate transition
      from a transparent shade to a pale rose nuance is evidence of the high
      professionalism. The eyes, the hair, the beard, the chiton, and the himation
      are outlined with virtuosity. The same representative style is
      characteristic of some other icons from Nesebar associated with the Strandja
      iconographic school.</p>
    </div>
    <div class="instructions">
    </div>
  </div>
  <div class="page" id="p8">
    <div class="content">
      <p>The image of Saint Nicholas by Tryavna iconographic school. The
      color exposition is expressive, the stylization of the clothes, the hands
      and the face reach geometrical schematism. There is a tendency to pronounced
      elegance through elongated proportions and rhythmic. One can feel the
      confidence of the performance. The composition, the proportions, the
      character of the image and the harmony of the colored spots suggest that the
      author is a great master with a style of his own from the Tryavna
      iconographic circles.</p>
    </div>
    <div class="instructions">
    </div>
  </div>
</div>
</body>
</html>

```

After the completion of the manifest generation, the manifest gets stored in the SCORM package, along with all previously stored files and some .xsd schemas for the validation of SCORM XML documents as it is required in SCORM. Finally, the SCORM package gets compressed into the final Package Interchange File (.zip), ready to get imported in any SCORM compliant LMS.

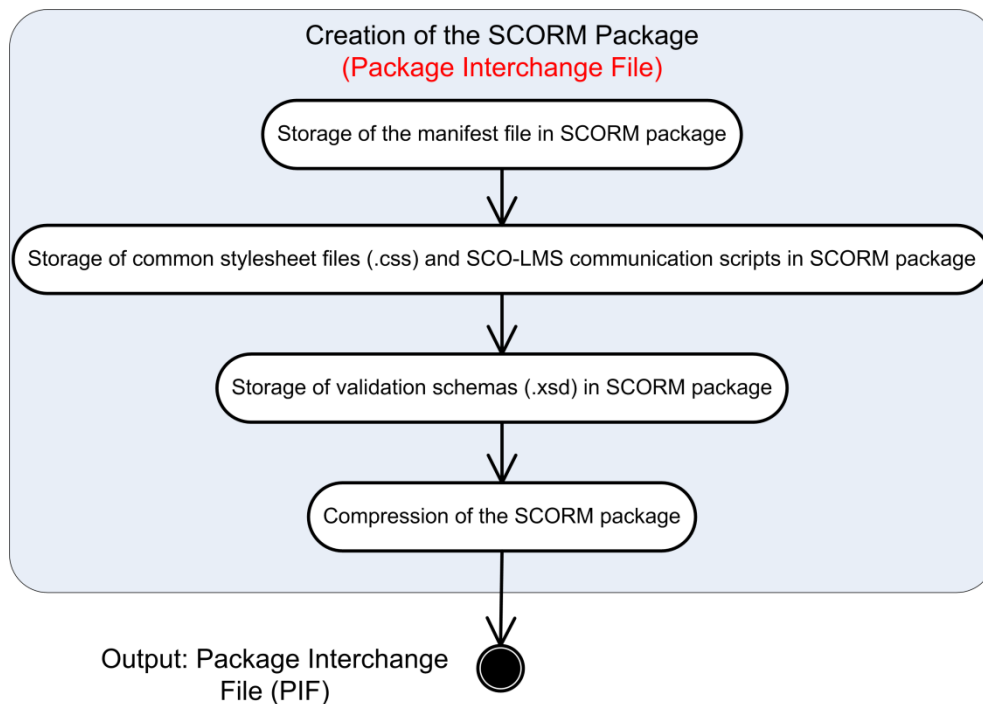


Figure 5.15 Creation of the final SCORM Package (Package Interchange File - PIF)

5.3. Summary

In this chapter, the implementation of the framework and architecture of this thesis in the context of LOGOS European project has been presented. Specifically, the formulation and description of LOGOS objects (MOs, DOs, AOs, LOs and COs) exploiting METS has been presented, as well as the services of the corresponding repositories that host them, according to the IMS DRI specification. Afterwards, the dynamic creation of personalized courseware has been described and its integration with the overall architecture that has been based on the framework of this thesis for the dynamic creation of pedagogy-driven personalized learning experiences. A Learning Designs Editor has been implemented for the creation and management of abstract training scenarios according to the instructional model of this thesis and its architecture and functionality have been presented. Finally, the transformation of Courseware Objects to SCORM Packages by the Transformation Component has been described in detail for the delivery of the final learning experiences to Learners through eLearning Applications.

Chapter 6. EXPERIMENTATION AND EVALUATION

6.1. Introduction

In this chapter the experimentation and evaluation processes of the framework presented in this thesis that have been conducted in the context of the European projects DELOS and LOGOS are presented.

6.2. Preliminary Experimentation and evaluation in DELOS Project

In order to acquire preliminary evaluation data regarding our proposed personalization framework we have conducted a controlled experiment to find out if systems that follow our approach can perform better than other systems that offer the same (static) courseware to all learners. This was a controlled experiment not performed in a real-life situation (it is a laboratory experiment) nor does it compare our personalization approach to other personalization approaches. Real-life evaluation was performed in LOGOS evaluation phase using its specified target user groups, as described later in this chapter. The purpose of this preliminary experimentation was to validate the usefulness of our approach as opposed to one-fits-all solutions.

6.2.1. Experimental Setting

In order to evaluate our personalization system we engaged a domain expert to manually construct a course about the “Sharable Content Object Reference Model (SCORM) eLearning standard” as (s)he would do if it was intended to teach this subject in a class. The expert following the teaching procedure that always uses constructed a structure of the topics to be taught along with appropriate learning material that is being associated with each topic.

We engaged the same domain expert to construct a learning design for teaching the same subject following our approach. That means that (s)he had to construct several abstract training scenarios (training methods) for teaching the same subject for some combinations of learning styles, educational level and difficulty (lets say {general to specific, further, high} and {example oriented, further, low}). In each activity (s)he has to specify the preferred learning object characteristics that (s)he considers to be appropriate to support the corresponding learning activity, without binding specific learning objects with activities.

We then selected 10 target learners with background in computer science but varying in their knowledge about eLearning standards and specifically SCORM. We separated those learners in two groups of 5 persons each. The first group attended the manually constructed course (control group), while each member of the second group (test group) had a personalized learning experience generated from our personalization system taking

into account the specific educational needs of each learner. In order to classify the Learners with respect to the chosen Learning Style taxonomy we have used an appropriate questionnaire. Some indicative questions were:

“When considering a body of information, I am more likely to (a) focus on details and miss the big picture, (b) try to understand the big picture before getting into the details”,

“Once I understand (a) all the parts, I understand the whole thing, (b) the whole thing; I see how the parts fit”

The following table summarizes the design of the experimentation conducted.

Purpose	<p>Investigate the impact of personalization in the learning time needed by a learner to complete a course.</p> <p>Investigate the personalized learning outcomes and compare with a situation where no personalization is present (static courseware).</p> <p>Investigate the relationship between the learning effectiveness and personalization.</p>
Objects	Computer Science and Computer Engineering graduates with varying knowledge about eLearning standards and specifically SCORM.
Range of experiment	<p>Volunteers recruited from the postgraduate students and the staff working at the Department of Electronics and Computer Engineering Department at the Technical University of Crete.</p> <p>Random grouping of Learners.</p>
Organization	<ol style="list-style-type: none"> 1. Recruiting the volunteers 2. Planning the experimental time table 3. Actual experimentation 4. Analysis of results using certain metrics
Experimental time	<p>Add up to 100 minutes for each learner.</p> <ol style="list-style-type: none"> 1. Training on the experimentation process and objectives:

	<p>15 minutes</p> <ol style="list-style-type: none"> 2. Pre-test: 10 minutes 3. Attending the course (personalized or not): up to 60 minutes; 4. Post-test: 15 minutes
Method	<ol style="list-style-type: none"> 1. Grouping the ten learners into two groups randomly: five learners in each group (the first group does not attend a personalized course). 2. Training the learners in order to be able to use the software. 3. Classifying Learners in terms of their Learning Style using simple questionnaire. 4. Testing before learning. The score for each learner is recorded. 5. Learning by using learning system on computer. The learning time for each learner is recorded. 6. Testing after learning. The score for each learner is recorded.
Evaluation metrics	<p>We compute the following metrics for both the control group and the test group:</p> <p><i>ALT</i>: Average learning time.</p> <p><i>ASR</i>: Average success rate (grade for the post-test normalized in $[0, 1]$).</p> <p><i>ALE</i>: Average learning efficiency (ratio of success rate and learning time – success rate per minute).</p> <p><i>ALT-PG</i>: Average learning time per pretest group. We define two groups of learners in both the control and the test group. The first contains those with high score in the pretest and the second those with a low-score in the pretest.</p>

	<p><i>ASR-PG</i>: Average success rate per pretest group. We define two groups of learners the same way as in the ALT-PG metric.</p> <p><i>ALE-PG</i>: Average learning efficiency (ratio of success rate in the post-test and learning time – success rate per minute) per pretest group. We define two groups of learners the same way as in the ALT-PG metric.</p> <p><i>ALT-LS</i>: Average learning time per learning style. Both the control and the test group are divided into two groups depending on the learning style of learners.</p> <p><i>ASR-LS</i>: Average success rate per learning style. Both the control and the test group are divided into two groups depending on the learning style of learners.</p> <p><i>ALE-LS</i>: Average learning efficiency per learning style (ratio of success rate and learning time – success rate per minute). Both the control and the test group are divided into two groups depending on the learning style of learners.</p>
--	---

6.2.2. Experimental Results

Figure 6.1 shows the learning time needed to attend the learning experience. It is evident that without personalization (control group) the learning time is greater, which implies that personalization results in less required time for learning.

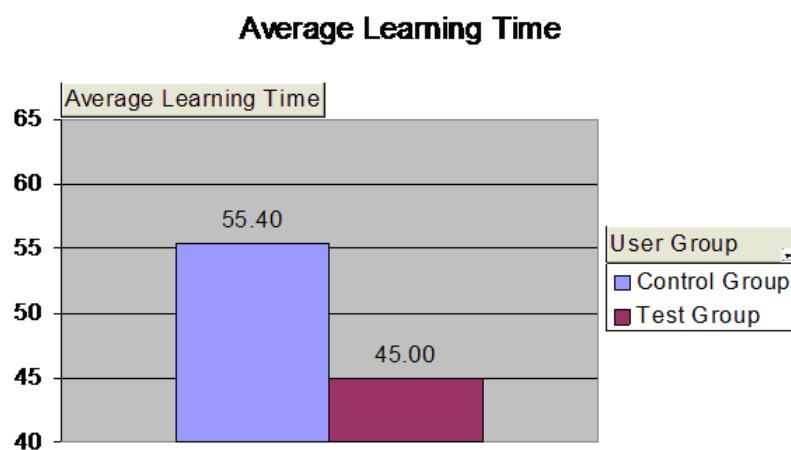


Figure 6.1 Average Learning Time in minutes.

Figure 6.2 shows the average success rate, i.e. the average grade that the learners receive in the test after the learning. It is evident again that with personalization (test group) the

results are better meaning that personalized courses result in better learning effect by approximately 11%.



Figure 6.2 Average Success Rate normalized in $[0,1]$.

In terms of learning efficiency, as shown in Figure 6.3, personalization has a stronger impact: 37% better results.

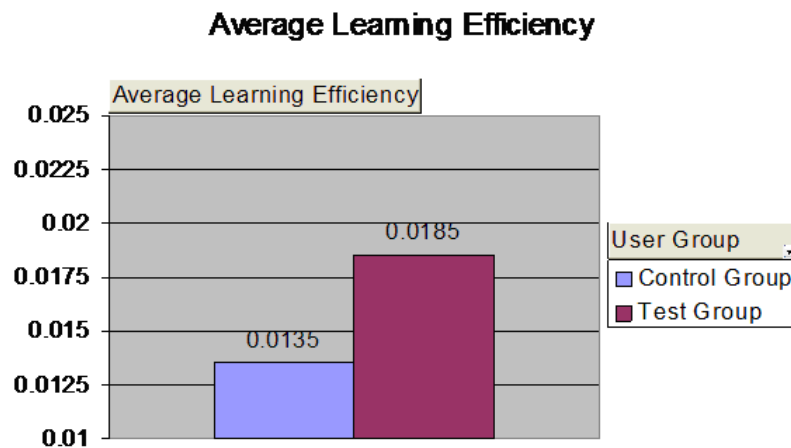


Figure 6.3 Average Learning Efficiency computed as success rate per minute of learning time.

In order to evaluate the impact of personalization depending on the previous knowledge of learners, we have computed the three metrics presented in the following three figures using a grouping of learners with respect to their performance in the pretest. We have grouped them in two groups: those with high score in the pretest (success rate 0.5 or higher) and those with low score in the pretest (success rate under 0.5). In terms of learning time (see Figure 6.4) both low score and high score groups present similar improvement when personalization is employed with a slight antecedence of the high score group (21.65% improvement as opposed to 20.55% improvement for the low score group).

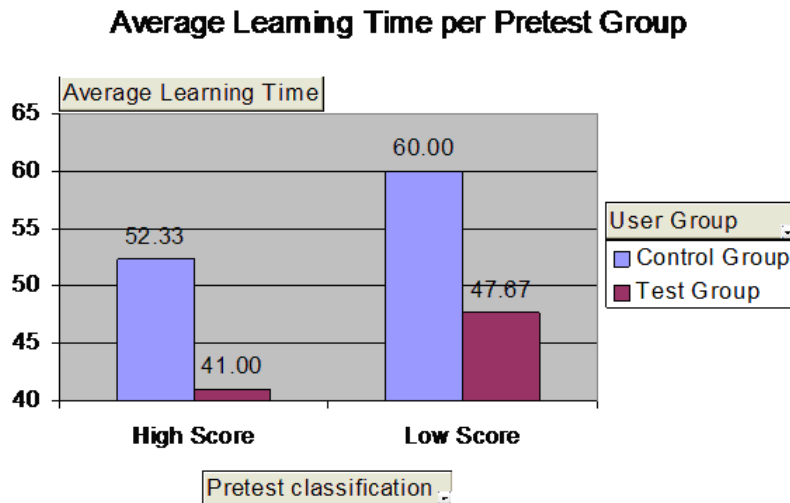


Figure 6.4 Average Learning Time for learners that received a high score in the pretest and for learners that received a low score in the pretest.

In terms of success rate, the high score group performs better in comparison with the low score group (see Figure 6.5). The high score group has 18.75% improvement while the low score group has a 12.30% improvement.

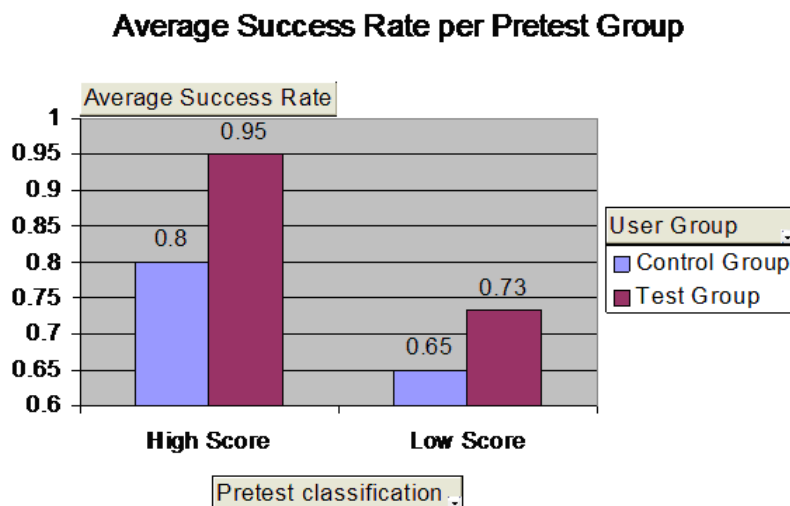


Figure 6.5 Average Success Rate normalized in [0,1] for learners that received a high score in the pretest and for learners that received a low score in the pretest.

The stronger impact of personalization in the high score group is even more evident when the learning efficiency metric is used (Figure 6.6). The high score group has 51.63% improvement while the low score group has a 42.60% improvement. The higher impact of personalization in the high score group is justified by the fact that our personalization approach takes into account the previous knowledge of learner in order to create personalized courseware that contains only the necessary learning material to address the learning needs of the learner without repeating things that are already learned. This results in less learning time and better exploitation of the learning time.

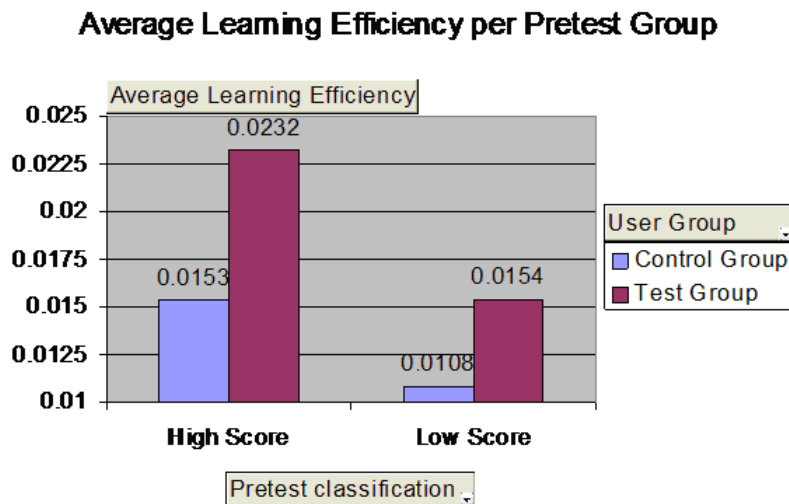


Figure 6.6 Average Learning Efficiency computed as success rate per minute of learning time for learners that received a high score in the pretest and for learners that received a low score in the pretest.

The next thing that we investigated is the impact of learning style in the learning effect. We have grouped the learners in both the control and the test group into two groups. The first one contains the learners with learning style “general-to-specific”, i.e. the learners that learn better when they study first the general concepts about a certain topic and then study the details. The second group contains the learners that have “specific-to-general” learning style. Taking into account that the static courseware given to the control group has been designed following a principle-oriented approach, we expect to see a higher impact of personalization in the case of “specific-to-general” learning style. Indeed, the analysis of the experimental results (Figure 6.7, Figure 6.8 and Figure 6.9) justifies this expectation.

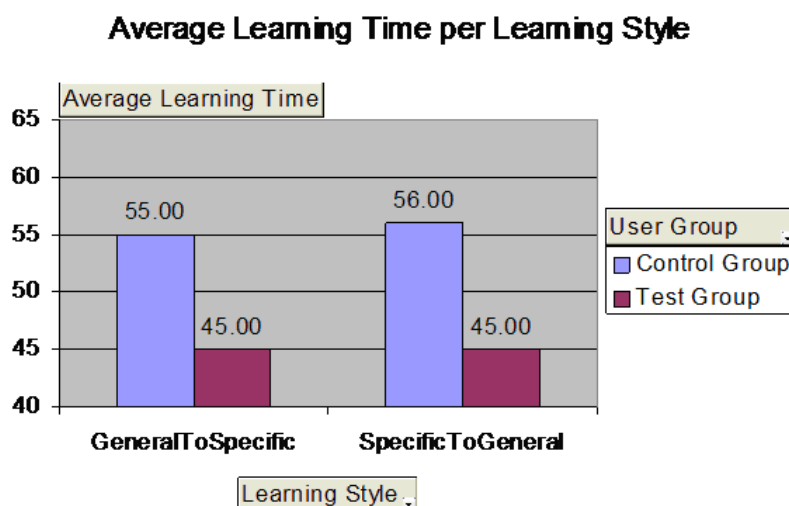


Figure 6.7 Average Learning Time per Learning Style of Learners.

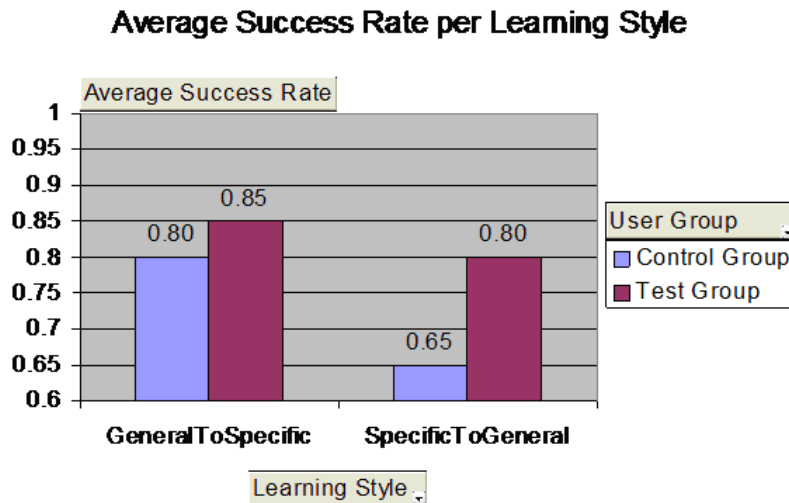


Figure 6.8 Average Success Rate normalized in $[0,1]$ per Learning Style of Learners.

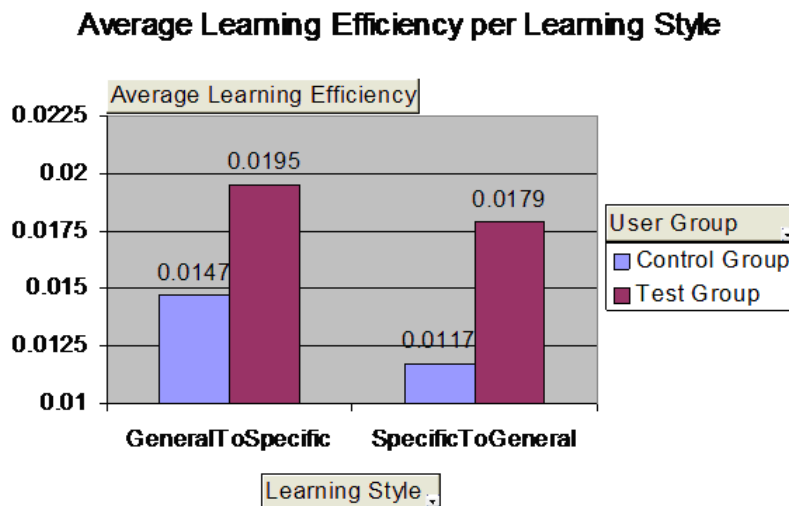


Figure 6.9 Average Learning Efficiency (computed as success rate per minute of learning time) per Learning Style of learners.

6.3. Experimentation and evaluation in LOGOS Project

The validation of the LOGOS platform combined “Formative and Summative evaluation”: “Formative evaluation” is an evaluation of an unfinished user interface, which aims to expose usability problems that exist in the development iteration. This would contrast with “Summative evaluation”, which is done when the interface is complete, and with “human factors testing”, which is done in a more carefully controlled research setting.

6.3.1. Experimental Setting

In the Summative evaluation phase, feedbacks of real end-users of the LOGOS system have been collected and analyzed [Corep, Eden, and UniBrighton, 2009]. The feedbacks have been collected from two target groups: authors and learners of ubiquitous learning materials, representing real end-users of the system.

The feedbacks have been created after:

- Authors use the LOGOS Authoring Studio and playout systems following a selected set of authoring scenario.
- Learners take part of a ubiquitous learning experience, which is created based on a selected learning scenario.

The reflections of the two target groups shall provide feedback on the LOGOS system according the following structure:

Authors/teachers/educationalists	Learners
Usability in terms of acceptability, user experience, satisfaction and willingness of use, measured by means of questionnaires and interviews, including comparison of experience with other delivery means and devices.	Usability in terms of acceptability, user experience, satisfaction and willingness of use, measured by means of self-administered questionnaires and focus groups, including comparison of experience with other delivery means and devices.
	Personalization efficiency in terms of inventorying the opinions, demands, needs and satisfaction of users by means of self-administered questionnaires and focus group design.

Although expert evaluation provides valuable feedback, often including solutions to identified usability problems, it cannot be a substitute for evaluation carried out with authentic end user representatives, as experts evaluators cannot fully take on the personas of real users. Therefore, the cognitive walkthrough and heuristic evaluation stages will be complemented, once an integrated version of the software is robust enough for use, in observation sessions. Typical tasks will again be extracted from the scenarios and end users will be invited to carry out these tasks in LOGOS, while providing a running commentary as they do so. Their interactions will be recorded on video and audio, so that the analysis of their commentary (or Thinkaloud Protocol) can be analysed in conjunction with keystroke records and screen displays. In addition, a short set of questions seeking subjective reactions to the software will be administered after each user observation session. Testers will be the real end users envisaged by the designers, i.e. eLearning designers, Lecturers and Learners.

6.3.1.1. Design of Indicators and metrics for Authors

Despite the large number of e-learning systems now available, one of the barriers to successful deployment of technology-based learning is the lack of high quality systems tailored to the needs of individual users and groups [Corep, Eden, and UniBrighton, 2009]. Quality, which means a pleasant thing, is an abstract term that assumes specific meanings according to the context in which it is used. From the end of the 1970s, in the software engineering context, some factors have been introduced as measures of the software quality. McCall affirms that quality factors represent attributes or characteristics

of the software that a user or a client of the software couples with the quality of the software [McCall, 1994]. Details on the first studies on quality factors can be found in [McCall, 1994; Boehm, 1978].

When speaking of quality, it is important to consider the regulations for quality certification. In particular, the ISO/IEC 9126 establishes standards for ensuring the quality of a software product (ISO 9126, 1991), emphasizing that the quality is an attribute that depends on the users, the context, the goal, and the cost of the product.

Within the LOGOS framework, it was decided to use for the Authors end-user evaluation the IsoMetric Questionnaire. The IsoMetrics Questionnaire comprises 75 items operationalising the seven design principles of ISO 9241-10, thus the Ergonomic principles which apply to the design of dialogues between humans and information systems:

- suitability for the task,
- suitability for learning,
- suitability for individualisation,
- conformity with user expectations,
- self descriptiveness,
- controllability,
- error tolerance.

The summative version of IsoMetrics showed high reliability of its subscales and gathered valid information about differences in the usability comparing different software systems.

6.3.1.2. Design of Indicators and metrics for Learners

During end-user experiments, we collected feedback from participants of experimentation who used the LOGOS system via the specifically created coursewares by the LOGOS Authoring Studio via the LOGOS Media servers. The feedback was collected from learners of ubiquitous learning materials, representing real end-users who took part of a ubiquitous learning experience, which was created based on a selected learning scenario. An experimentation session consisted of the group of learners, Experimentation leaders, Observers, the LOGOS platform including Manuals and Tutorials, Created Courses based on Selected Scenarios for learners, Task scenario booklets for learners on the steps of experimentation, Participation records: participation forms, explanation sheet, Thank you forms, Privacy agreements, Observation sheets,

Focus Group Procedures and record sheets and transcripts administered by experiment leaders as well as Self-Administered Questionnaires for learners to record their experiences. After the learners performed the experiments with their selected courses, on their preferred device, they were asked to fill in the online Self-Assessment Questionnaire where feedback on usability and acceptability issues was collected with.

Afterwards, the learners and observers took part of a focus group meeting facilitated by the experimentation leaders trained beforehand. The focus-group meeting session served several functions. It allowed the end-users to say whatever they like, which allowed the gathering of qualitative data on acceptability and learner preference. It provided important information about each end-user's rationale for performing specific actions, and it allowed the collection of subjective preference data about the system and its supporting documentation. The meeting also allowed the experiment leader to introduce his/her observations during the experimentation as well as feed in results of the expert evaluations.

The group discussion was 'focused' or structured by a 'facilitator' and, in addition, one or two additional observers or recorders gathered data on the outputs of the discussion. Focus group observation sheet allowed the experiment leader to document the discussion

Regarding Learner end-user assessment, "USE" Usability questionnaire based on Nielsen's quality criteria was designed. This short self-administered questionnaire was used to measure the most important dimensions of usability for users including issues for software, services, and user support materials. It allowed meaningful comparisons of user experiences in different domains, even though testing of the coursewares created with LOGOS Authoring tools happened at different times and under different circumstances. Following previous studies' suggestions, learner users were evaluating their learning experiences with LOGOS courses according to four usability dimensions: i) Usefulness, ii) Satisfaction, iii) Ease of Learning, iv) Ease of Use as well as addressed the acceptability of the ubiquitous learning experience. The LOGOS environment was assessed in ubiquitous situations so that digital TV, mobile phone and PC experimentations could take place at the same time.

6.3.2. The "Learning LOGOS through LOGOS" course development phases and corresponding material

The LOGOS Platform is an innovative Information System that addresses the need to efficiently support ubiquitous learning services exploiting the vast amount of multimedia content residing at digital libraries and archives, thus building a ubiquitous knowledge-on-demand infrastructure.

To this end, LOGOS conortium partners have worked intensively for three years

- to study appropriate pedagogical approaches, available technologies and well-accepted standards
- to design the front-end (LMS components) and the back-end (Authoring Studio and Repositories) of the LOGOS Platform as well as to specify the representation models (formats) of various kinds of objects that the Platform should manage
- to implement the Platform following an incremental prototyping approach that started in the first year of the project and proceeded in iterative improvement cycles for more than two years

During the above activities all partners gained valuable experience and knowledge regarding the best possible usage of LOGOS technologies and methodologies and they have gained valuable insights regarding the core concepts and principles behind LOGOS vision and objectives. This knowledge is reflected in various outputs of the project such as the official deliverables, dozens of internal documents, the manuals and tutorials that accompany LOGOS Platform and especially those that are intended for LOGOS Authors, i.e. the creators of learning content. However, most of the knowledge acquired remained in tacit form and near the end of the project, the partners realized that the knowledge regarding the very domain of LOGOS should be encoded in the best possible way in order to be used as a valuable means for exploiting LOGOS technologies beyond LOGOS consortium.

In other words, the consortium, realized the need for a more attractive and systematic training of future LOGOS Authors so as to be able to play the user roles of LOGOS back-end:

- **Knowledge Managers:** They create and maintain domain-specific ontologies, necessary for the semantic description of audiovisual content. They are domain-experts able to specify domain-specific concepts in Conceptual Graphs. The Authoring Studio Ontology Management Tool is used by Knowledge Managers to create and maintain the core concepts of the domain specific ontologies. It also provides functionality to create and maintain constraints, indexing templates and rules.
- **Media Integrators:** They identify material residing at external digital libraries and archives and import it into the LOGOS Media Server through its web-based user interface. After importing the material they can describe it with administrative metadata so that it is searchable and usable inside the LOGOS environment.
- **Annotators/Indexers:** They annotate, segment and semantically index the raw audiovisual material in order to create and maintain digital objects. The tool they

use from the Authoring Studio is the Content Description Tool that provides all the necessary functionality to segment, annotate and semantically index multimedia content. Moreover, this user role is supported by two search and retrieval tools, namely the Navigation-based Information Retrieval Tool and the Graphical Conceptual Graph Querying Tool so that it is possible to search for digital objects.

- **Educationalists:** They use the Description Tool for Learning Objects to create reusable learning objects. Their work starts with the selection of appropriate digital objects. These objects (and combinations of them) are then enriched with educational metadata for a given pedagogical use.
- **Courseware Developers:** They create, maintain and publish static courseware for learners. The creation of static courseware may exploit the facilities of the Courseware Repository to create dynamically courses and then modify the dynamically created courses. The Authoring Studio tools used by Courseware Developers are the Courseware Objects Editor to create static courseware or modify dynamically created courseware, and the Publishing Tool to publish courseware as ready-to-be-delivered courses, thematic web folders, interactive videos, etc.
- **Learning Designers:** They use the Learning Designs Editor to create abstract training scenarios so that they could be used for the dynamic creation of personalized courseware according to LOGOS personalization framework.

To satisfy the above need, the project partners agreed to consider the LOGOS domain as a stand-alone learning domain. This way, it was possible to elaborate the building blocks for supporting potential LOGOS Authors with appropriate introductory courses that will help them build the necessary competencies and skills to fully exploit LOGOS product offer. These building blocks are essentially the Ontology, Media Objects, Digital Objects, Learning Objects, Courseware Objects and Learning Designs that are developed by using the corresponding tools of the LOGOS Authoring Studio.

Considering LOGOS domain as a stand-alone learning domain and developing courseware to address potential users of the LOGOS Authoring Studio Tools as learners has several advantages: We offer additional help to people that want to get familiar with LOGOS concepts and tools apart from the manuals and tutorials that we have already developed taking into account the different learning styles of our potential users. We take advantage of the already available content regarding LOGOS authoring studio usage. Note also that the tools themselves are considered, in this approach, as an important element of the learning process (active learning). E.g. activities allowing direct experimentation with the tools for Activists, Walkthroughs and tasks for experimentation

for Pragmatists, Video Tutorials for Reflectors, description of the tools concepts and purpose for Theorist along with manuals, tutorials and walkthrough etc. Consequently, LOGOS domain provides a lot of material and tools that can be used to support all possible learning styles, either passive or active.

The details regarding the development of the above building blocks are presented in the following sections as well as how they have been used in order to provide LOGOS candidate Authors with personalized courses that exploit the LOGOS personalization framework and demonstrate its features and efficiency in various learning situations.

From a user's point of view, one could imagine various authoring scenarios in order to create courseware for Learners using content residing at external archives. The most simple and straightforward scenario that is described here is the bottom-up scenario that describes the gradual development of higher level objects from lower level ones, starting from the creation of Media Objects. This overall scenario has been followed in the development of the LOGOS course and is depicted in the activity diagram of Figure 6.10.

The editing process starts from the creation of Media Objects and Ontologies. These form the basis of creating Digital Objects that are further used to create higher level objects such as Learning Objects and Courseware Objects. The creation of Media Objects and the creation of Ontologies are two activities that can take place in parallel.

As soon as Media Objects, representing interested material coming from external content archives, and Ontologies (i.e. conceptualizations of certain domains) are available it is possible to create Digital Objects. Digital Objects creation is essentially an activity that uses the available Media Objects in order to attach appropriate metadata to them (or parts of them) including semantic annotations that are created using the available ontologies.

Using the Digital Objects created, one can further create Learning Objects as collections of related Digital Objects that can be used to accomplish a certain learning objective.

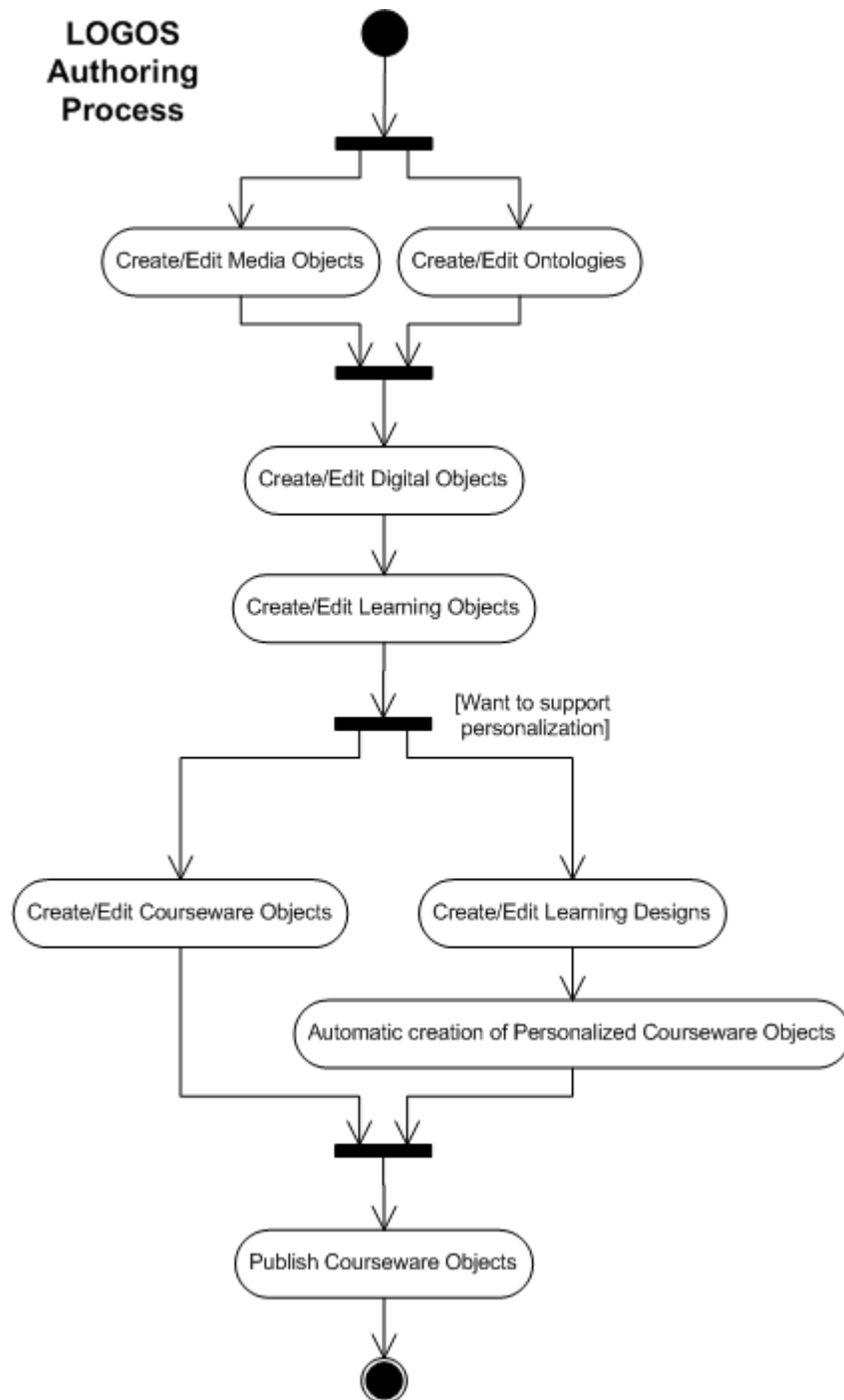


Figure 6.10 Overall authoring process in LOGOS

The usage of Learning Objects in order to create Courseware Objects can be done in two ways (they are presented in the activity diagram as two parallel activities): First of all one can statically create Courseware Objects by defining hierarchies of Learning Objects and by specifying their sequencing and presentation characteristics. This is the most straightforward option. Another option comes into play when one wants to support personalization. In that case, appropriate Learning Designs should be defined first. These are abstract training scenarios that capture the pedagogical characteristics of a training process for a certain subject without direct reference to the Learning Objects that can be

used in order to implement this training process. The binding of training activities with the Learning Objects is done by an automatic mechanism that is able to create personalized Courseware Objects exploiting information about the user characteristics (this information can come from a Learner Profile). The output of this automatic process is Courseware Objects that are similar to the Courseware Objects created manually in the case of static Courseware Creation.

The final activity in the authoring process is the publishing of Courseware Objects in order to be ready for consumption by the Learners using different devices (PCs, mobile devices, digital TV). Publishing a Courseware Object essentially means to decide on how the content will be presented to the final user and what devices are going to be supported.

In the next sections the development phases of the LOGOS domain course are described as well as the results of each phase. The development phases are organized as follows:

- 1) Development of a domain ontology describing the LOGOS Project domain
- 2) Development of the learning resources
 - Development of training material and appropriate adaptation of existing resources
 - Development of Media Objects
 - Development of Digital Objects
 - Development of Learning Objects
- 3) Development of Learning Design with training methods for Honey & Mumford's learning styles
 - Training Method for Activists
 - Training Method for Reflectors
 - Training Method for Theorists
 - Training Method for Pragmatists

Before proceeding to the description of the LOGOS domain course development phases described above and the corresponding results, the selection of the Learning Style approach and the corresponding learning style evaluation method will be discussed.

6.3.2.1. Selection of the Learning Style Taxonomy and Learning Style evaluation method

In Chapter 2 we mentioned that learning has mainly to do with how learners perceive and process information [Sarrikoski et al., 2000]. So, in order to create the most suitable learning experiences for learners' learning styles, we shouldn't measure the whole personality or what is the most suitable environment for each learner but we should concentrate on the learning process, information processing and experimental learning.

Towards this end, Kolb's, Honey and Mumford learning style models were considered as the most relevant candidates since they are categorized as being information processing model types or more specifically information processing models based on experiential learning [Sarrikoski et al., 2000], while the other models categorize the learner on the basis of less relevant aspects to learning (e.g. senses and the environmental factors).

For the purposes of our experiment we selected the Honey and Mumford learning style model. Since Honey and Mumford Learning Style Questionnaire is quite long, as it contains 80 questions, we thought that a shortened version of the questionnaire would be more appropriate. For example, IBM used a shortened version to investigate the learning styles of 365 of their managers [Honey et. al, 1992]. We decided to use another version of the questionnaire that was created in 3DE project [Del Corso et. al, 2003], containing 36 questions, since it can be easily completed by the Learners while in parallel gives very good results (see Appendix 7: 3DE Project Questionnaire).

6.3.2.2. Development of a domain ontology describing the LOGOS Project domain

A domain ontology describing the LOGOS Project domain has been developed containing about 100 concepts and their relations. The Ontology Management Tool (CoGUI) of the LOGOS Authoring Studio has been used for the development of this ontology (Figure 6.11 and Figure 6.12). A domain ontology describing the knowledge of a domain is used for the indexing of the related training material and the creation of Digital Objects, as well as in the formation of learning objectives, both at the level of Learning Objects and the Learning Designs.

In the Annex, the complete ontology using Conceptual Graphs XML (COGXML) is included. The CoGXML format allows representation of conceptual graphs in the format of XML documents.

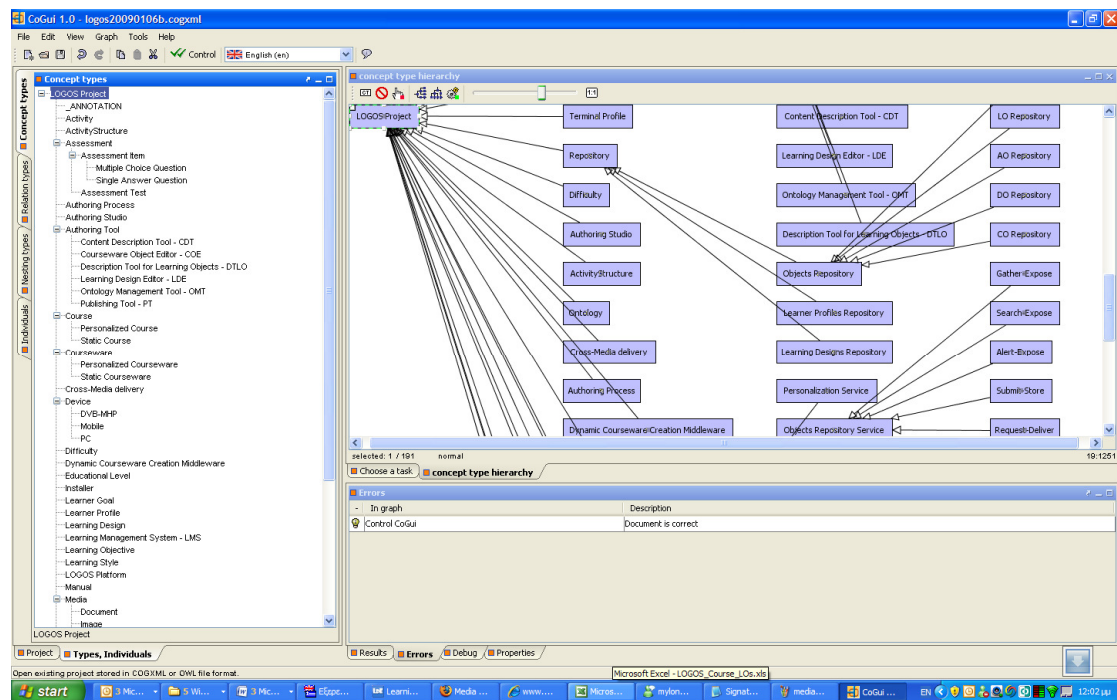


Figure 6.11 LOGOS Ontology Concepts (created with LOGOS Ontology Management Tool – CoGUI)

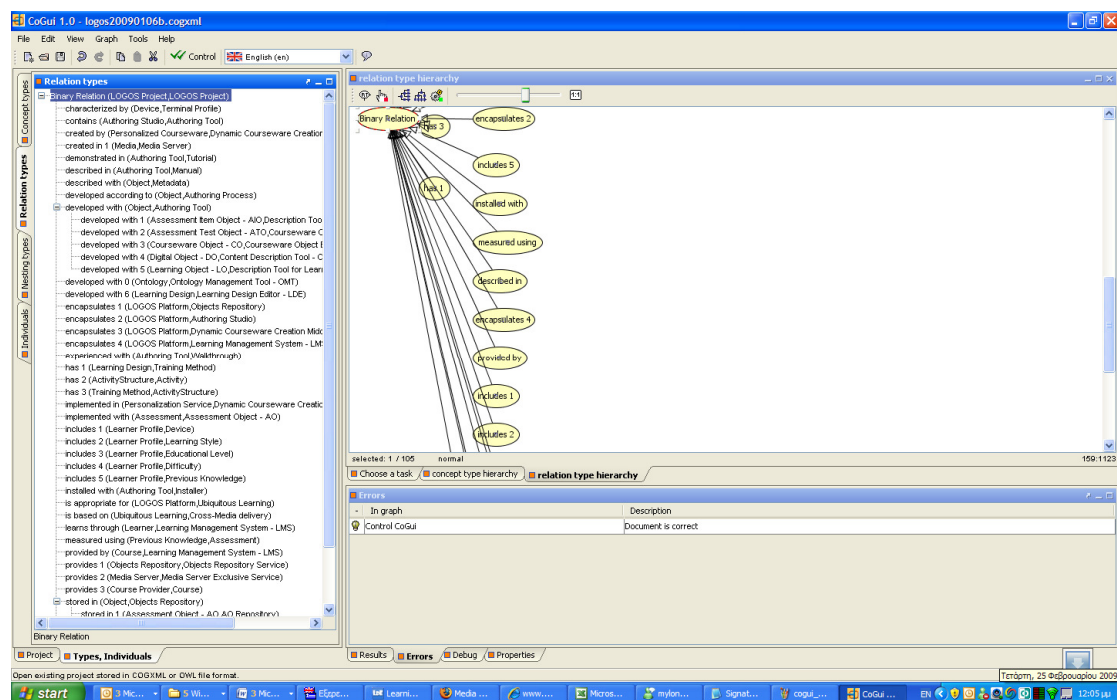


Figure 6.12 LOGOS Ontology Relations (created with LOGOS Ontology Management Tool – CoGUI)

6.3.2.3. Development of the learning resources

In this section the gradual development of Learning Objects from raw media using the Authoring Studio tools is described.

6.3.2.3.1 Development of training material and adaptation of existing resources

A number of media (raw content) has been developed or adapted from existing LOGOS material in order to create training material to support the teaching of the LOGOS domain to LOGOS Platform candidate users. Content residing in LOGOS deliverables and reports, Manuals, Video Tutorials and Walkthroughs has been exploited and appropriately adapted, but also new content developed in order to support the teaching process. Starting from the raw material, higher level objects (Media Objects, Digital Objects, Learning Objects) were created using the LOGOS Authoring Studio Tools in order to be used in the LOGOS candidate authors training.

6.3.2.3.2 Development of Media Objects

In the Annex, the complete ontology using Conceptual Graphs XML (COGXML) is included. Media Objects (MOs) correspond to media (raw content) coming from external content archives. A large amount of media (~250) of several types (html pages, videos, images, doc, pdf, flash objects etc.) corresponding to training materials regarding LOGOS domain have been uploaded and registered to the Media Server, forming the so called Media Objects. Due to their large amount, Media Objects are not presented here one by one, but they are directly accessible on the Media Server (<http://212.92.2.161/mediaserver/>). If someone puts the value “LOGOS,” in the “Tags” field and presses the “Search” button, all Media Objects that have been created for the LOGOS domain will be retrieved.

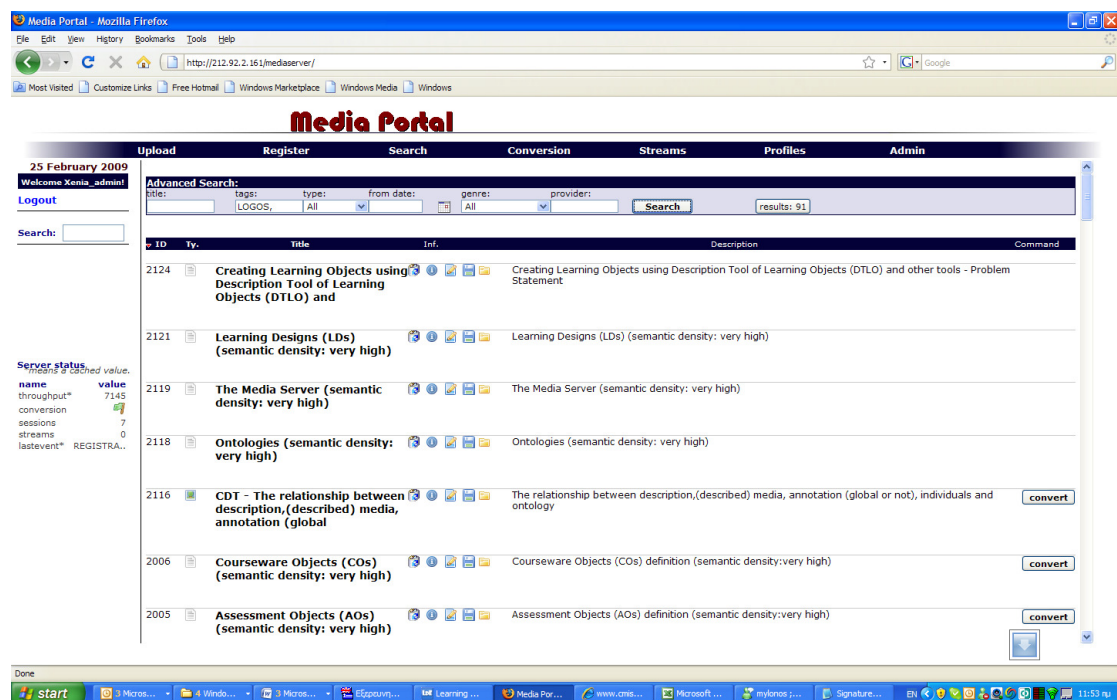


Figure 6.13 Media Objects for the LOGOS Project domain created and registered in the Media Server used from the upper levels for the creation of Digital Objects and Learning Objects

6.3.2.3.3 Development of Digital Objects

Digital Objects (DOs) are created on top of Media Objects and correspond to Media Objects or parts of them annotated and indexed with administrative and semantic metadata. A big number of Digital Objects have been created on top of Media Objects using the Content Description Tool (CDT), as illustrated in Figure 6.14 and Figure 6.15 and can be accessed and browsed through the same tool.

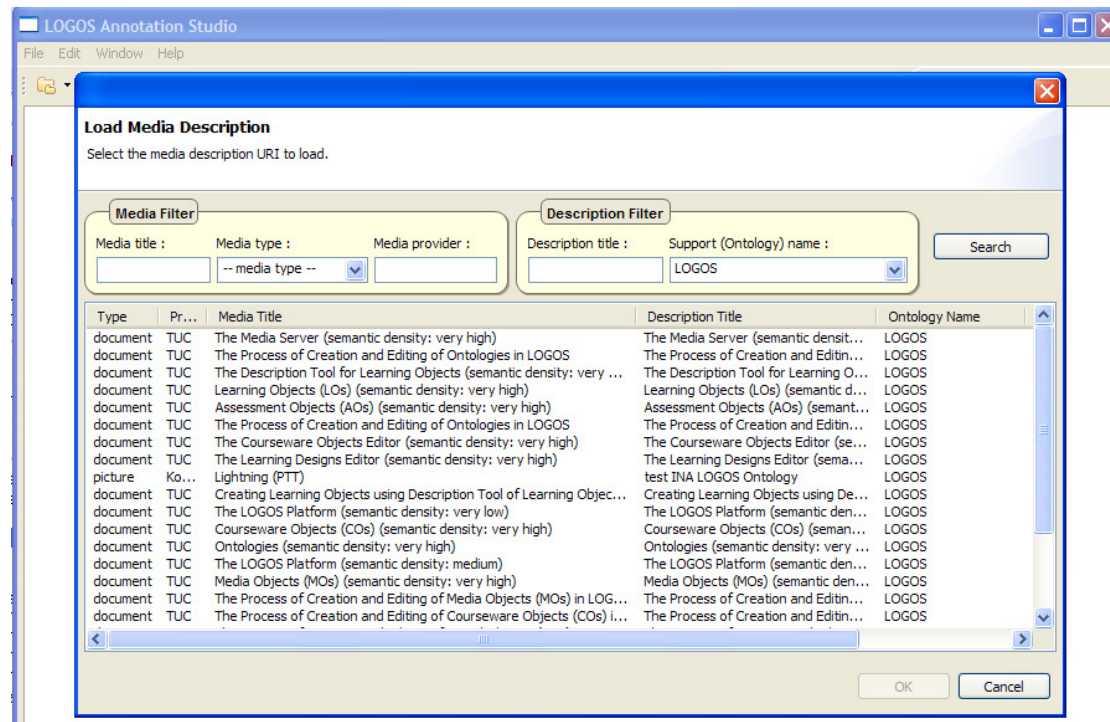


Figure 6.14 A number of annotated Media Objects (Digital Objects) that have been created for the LOGOS domain using Content Description Tool (CDT)

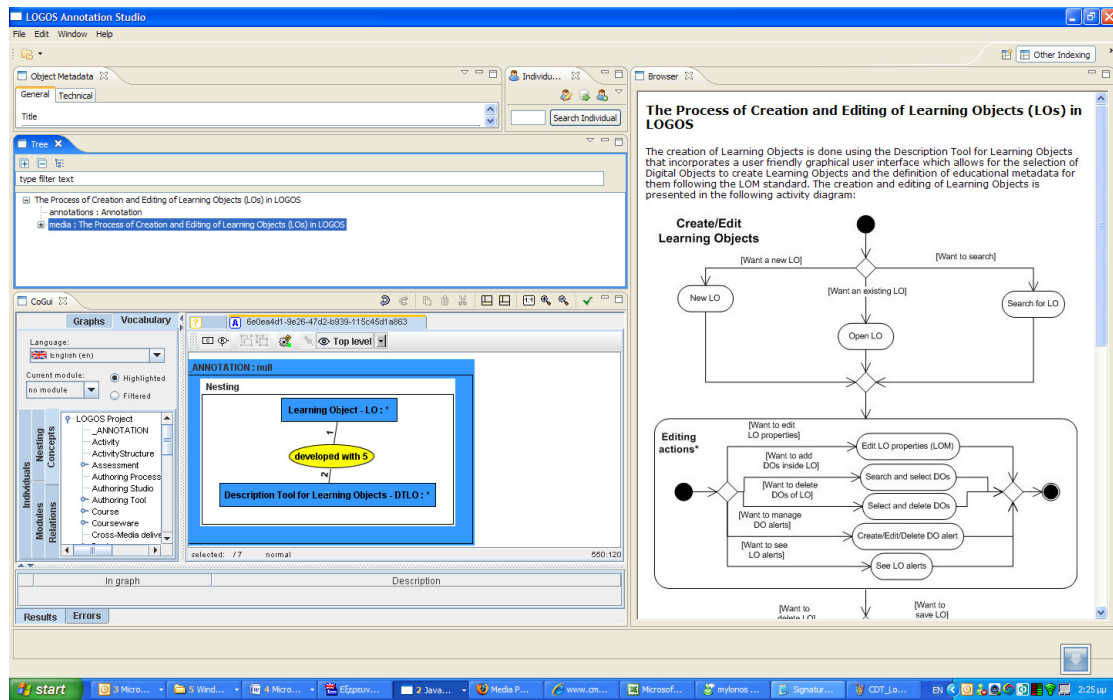


Figure 6.15 Annotation of a Media Object for the LOGOS domain through Content Description Tool (CDT)

6.3.2.3.4 Development of Learning Objects

Learning Objects (LOs) are built on top of Digital Objects and are described with educational metadata. Specifically, LOs in LOGOS are collections of DOs comprising self-standing units that fulfill certain Learning Objectives.

As mentioned in Section 3.4.1.2, in order to support a specific learning style, appropriate learning objects should be constructed according to the specific characteristics of each learning style described above. This also affects the selection of the Learning Objects' underlying content (Digital Objects). Here, we stress again that according to the framework presented in this thesis, learning objects metadata do not directly contain info about the learning style for which they are appropriate. There are two reasons for this fact: a) A learning object can be used to support more than one learning styles, b) Associating a specific learning style defined by a specific taxonomy in the learning objects metadata makes learning objects dependent on a specific learning style taxonomy and not reusable in other cases where a different learning style approach may be used. Using appropriate combinations of the values of LOM metadata elements declared in Section 3.4.1.2 (learning resource type, interactivity type, interactivity level, semantic density and learning objective using classification element), the appropriateness of a LO to support a specific learning style can be inferred.

A big number of LOs presented in the following tables have been developed for the LOGOS Project domain in order to be able to support different learning styles. The Description Tool for Learning Objects (DTLO) was used for their development (Figure 6.16 and Figure 6.17).

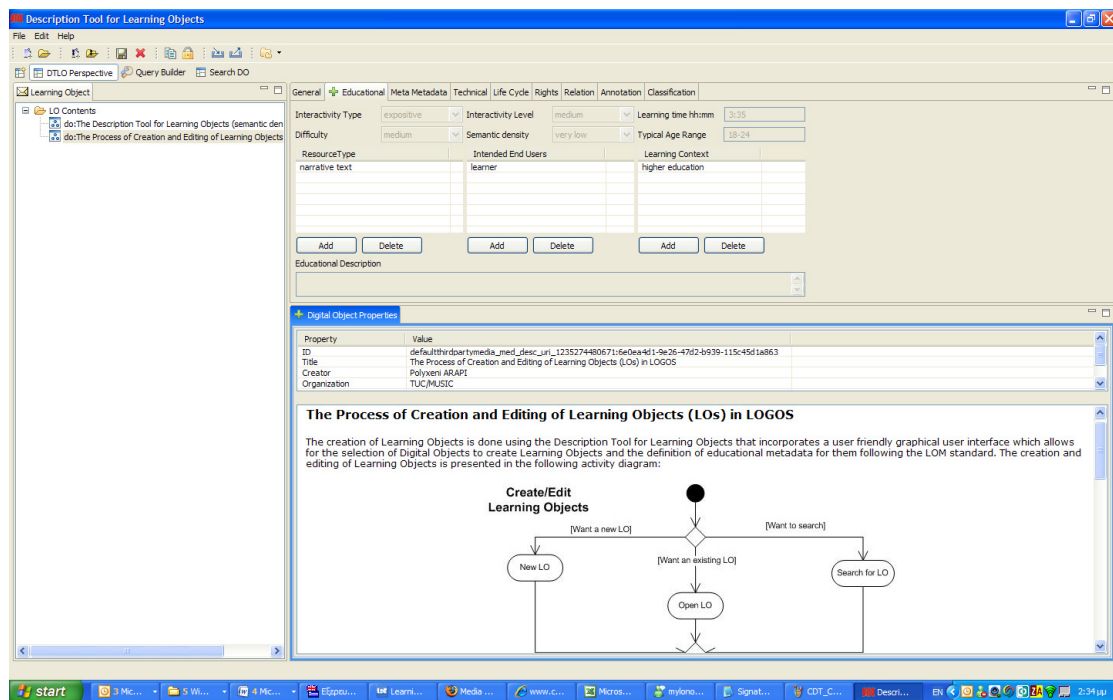


Figure 6.16 Creation of a Learning Object regarding LOGOS domain using the Description Tool for Learning Objects (DTLO)

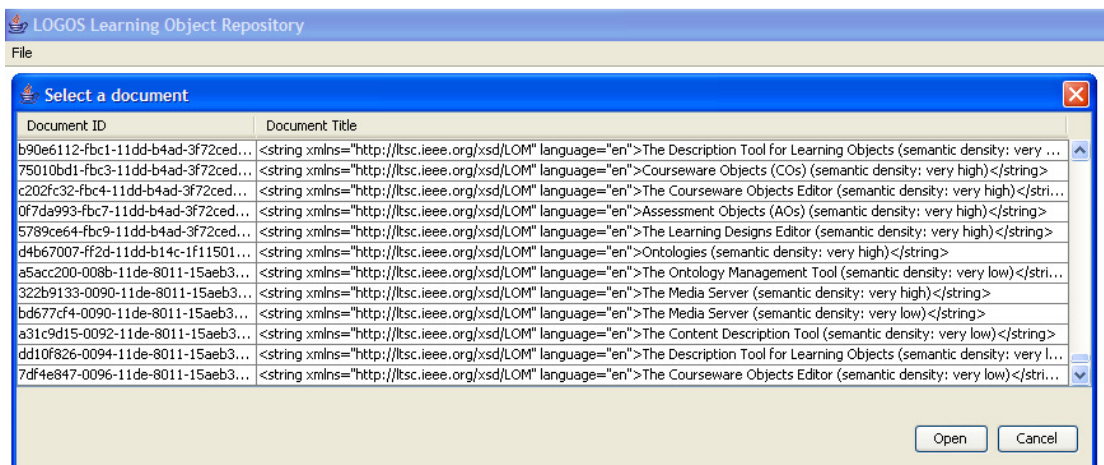


Figure 6.17 A number of LOs that have been developed for the LOGOS domain and retrieved from the Learning Objects Repository

In Table 6.1 the Learning Objects developed for the LOGOS course and their properties defined in the corresponding LOM metadata are presented.

Table 6.1 Learning Objects developed for the LOGOS course and their properties defined in the corresponding LOM metadata

LO Title	Properties
The LOGOS Project (semantic density:very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define LOGOS Project

The LOGOS Authoring Studio (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Authoring Studio
Ontologies (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: medium
	sD: very high
	lobv: define Ontology
The Ontology Management Tool (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Ontology Management Tool -OMT
Creating Ontologies using Ontology Management Tool (OMT) – Problem Statement	IRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Ontology Management Tool -OMT
Media Objects (MOs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Media Object - MO
The Media Server (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Media Server
Creating Media Objects using Media Server – Problem Statement	IRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Media Server
Digital Objects (DOs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Digital Object - DO
The Content Description Tool (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Content Description Tool - CDT
Creating Digital Objects using Content Description Tool (CDT) –	IRT: problem statement

Problem Statement	iT: active
	iL: very high
	sD: very high
	lobv: use Media Server
Learning Objects (LOs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Learning Object - LO
The Description Tool for Learning Objects (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Description Tool for Learning Objects - DTLO
Creating Learning Objects using Description Tool for Learning Objects (DTLO) and other tools – Problem Statement	IRT: problem statement
	iT: active
	iL: medium
	sD: very high
	lobv: use Description Tool for Learning Objects - DTLO
Courseware Objects (COs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Courseware Object - CO
The Courseware Objects Editor (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Courseware Object Editor - COE
Creating Courseware Objects using Courseware Objects Editor (COE) - Problem Statement	IRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Courseware Object Editor - COE
Assessment Objects (AOs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Assessment Object - AO
Creating Assessment Item Objects Using Description Tool for Learning Objects (DTLO) – Problem Statement	IRT: problem statement
	iT: active
	iL: very high

	sD: very high
	lobv: use Description Tool for Learning Objects – DTLO
Creating Assessment Tests Objects using Courseware Objects Editor (COE) – Problem Statement	IRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Courseware Object Editor – COE
Learning Designs (LDs) (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Learning Design
The Learning Designs Editor (semantic density: very high)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Learning Design Editor – LDE
Creating Learning Designs using Learning Designs Editor (LDE)	IRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Learning Design Editor - LDE
The LOGOS Project (semantic density: medium)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe LOGOS Project
The LOGOS Platform (semantic density: medium)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe LOGOS Platform
LOGOS Objects (semantic density: medium)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe Object
The LOGOS Authoring Studio (semantic density: medium)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: define Authoring Studio
Ontology Management Tool (OMT) Tutorial	IRT: simulation
	iT: expositive
	iL: low

	sD: very low
	lobv: use Ontology Management Tool -OMT
Ontology Management Tool (OMT) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Media Server User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Content Description Tool (CDT) Tutorial	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Media Server
Content Description Tool (CDT) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Description Tool for Learning Objects (DTLO) Tutorial for Learning Objects (LOs)	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Description Tool for Learning Objects - DTLO
Courseware Object Editor (COE) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Courseware Object Editor - COE
Description Tool for Learning Objects (DTLO) Tutorial for Assessment Item Objects (AIOs)	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) User Manual	IRT: narrative text

	iT: expositive
	iL: very low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Courseware Objects Editor (COE) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
Learning Designs Editor (LDE) Tutorial	lobv: use Courseware Object Editor – COE
	IRT: simulation
	iT: expositive
	iL: low
Learning Designs Editor (LDE) User Manual	sD: very low
	lobv: use Learning Design Editor - LDE
	IRT: narrative text
	iT: expositive
The LOGOS Project (semantic density: very low)	iL: very low
	sD: very low
	lobv: use Learning Design Editor - LDE
	IRT: narrative text
The LOGOS Platform (semantic density: vlow)	iT: expositive
	iL: very low
	sD: very low
	lobv: describe LOGOS Project
LOGOS Objects (semantic density: very low)	lobv: describe LOGOS Platform
	IRT: narrative text
	iT: expositive
	iL: very low
Ontologies (semantic density: very low)	sD: very low
	lobv: describe Object
	IRT: narrative text
	iT: expositive
The Ontology Management Tool (semantic density: very low)	iL: very low
	sD: very low
	lobv: describe Ontology
	IRT: narrative text
Containing Ontology Management Tool DO and Process DO	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Ontology Management Tool -OMT

Ontology Management Tool (OMT) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Media Objects (MOs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Media Object - MO
The Media Server (semantic density: very low) Containing Media Server DO and Process MO	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Media Server
Media Server User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Digital Objects (DOs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Digital Object - DO
The Content Description Tool (semantic density: very low) Containing Content Description Tool (semantic density: very high) and Process DO	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Content Description Tool - CDT
Content Description Tool (CDT) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Learning Objects (LOs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Digital Object - DO
The Description Tool for Learning Objects (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low

Containing The Description Tool for Learning Objects (semantic density: very high) and Process LO	sD: very low
	lobv: describe Description Tool for Learning Objects - DTLO
Description Tool for Learning Objects (DTLO) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Description Tool for Learning Objects - DTLO
Courseware Objects (COs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Courseware Object - CO
The Courseware Objects Editor (semantic density: very low) Containing The Courseware Objects Editor (semantic density: very high) and Process CO	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Courseware Object Editor - COE
Courseware Object Editor (COE) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Courseware Object Editor - COE
Assessment Objects (AOs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Assessment Object - AO
Description Tool for Learning Objects (DTLO) User Manual	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Learning Designs (LDs) (semantic density: very low)	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Assessment Object - AO
The Learning Designs Editor (semantic density: very low) Containing The Learning Designs Editor (semantic density: very high) and Process LD	IRT: narrative text
	iT: expositive
	iL: very low
	sD: very low

	lobv: describe Learning Design Editor – LDE
Learning Designs Editor (LDE) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Learning Design Editor - LDE
The LOGOS Project (semantic density: medium)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe LOGOS Project
The LOGOS Platform (semantic density: medium)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe LOGOS Platform
LOGOS Objects (semantic density: medium)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: describe Object
The LOGOS Authoring Studio (semantic density: medium)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: medium
	lobv: define Authoring Studio
Experimenting with CoGUI (from CoGUI site)	lRT: experiment
	iT: active
	iL: very low
	sD: low
	lobv: use Ontology Management Tool -OMT
Ontology Management Tool (OMT) Tutorial	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Media Server Cognitive Walkthrough	lRT: experiment
	iT: active
	iL: very low
	sD: low
	lobv: use Media Server
Content Description Tool (CDT) Cognitive Walkthrough	lRT: experiment
	iT: active
	iL: very low

	sD: low
	lobv: use Media Server
Content Description Tool (CDT) Tutorial	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Media Server
Description Tool for Learning Objects (DTLO) Walkthrough for Learning Objects (LOs)	IRT: experiment
	iT: active
	iL: very low
	sD: low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) Tutorial for Learning Objects (LOs)	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) Walkthrough for Assessment Item Objects (AIOs)	IRT: experiment
	iT: active
	iL: very low
	sD: low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) Tutorial for Assessment Item Objects (AIOs)	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Courseware Objects Editor (COE) Cognitive Walkthrough	IRT: experiment
	iT: active
	iL: very low
	sD: low
	lobv: use Courseware Object Editor – COE
Learning Designs Editor (LDE) Cognitive Walkthrough	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Learning Design Editor - LDE
Learning Designs Editor (LDE) Tutorial	IRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Learning Design Editor - LDE

6.3.2.4. Development of Learning Design with training methods for Honey & Mumford's learning styles

Learning Designs (LDs) are abstract training scenarios that capture the pedagogical characteristics of a training process for a certain subject without direct reference to the Learning Objects. Appropriate Learning Designs are applied from the LOGOS personalization processes to the construction of learning experiences where reusable learning objects are bound to the training scenario at run-time according to the Learner's individual needs and preferences.

Appropriate training methods have been developed with the Learning Designs Editor (LDE) in order to teach the LOGOS domain to Learners with different learning styles (according to Honey and Mumford) (Figure 6.18). In the tables that follow, the best fit Learning Objects that will be selected from the LOGOS personalization process and bound on the training methods activities at run-time are also presented.

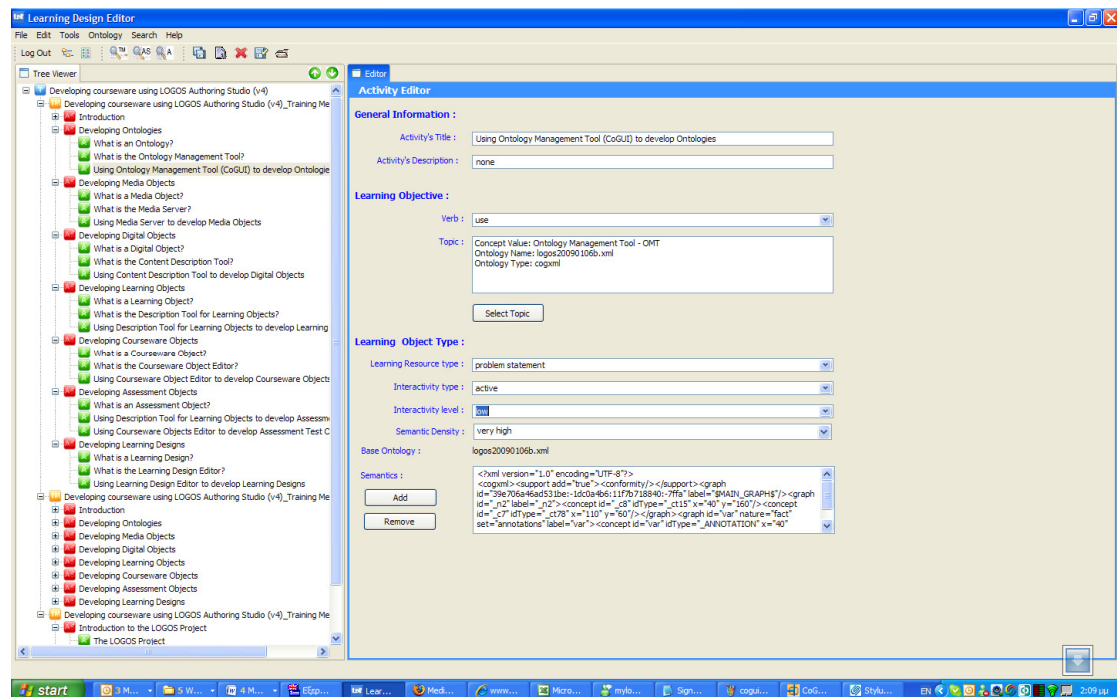


Figure 6.18 Development of different training methods for teaching the LOGOS domain in order to support Honey and Mumford learning styles implemented using the Learning Designs Editor (LDE)

6.3.2.4.1 Training Method for Activists (Concrete Experience)

Activists learn best from activities where there are new experiences/problems/opportunities from which to learn. They learn least from, and may react against activities where learning involves a passive role, ie., listening to lectures, monologues, explanations, statements of how things should be done, reading, watching.

Consequently, a Training Method for Activists should:

- not include too much theory. Thus we include only definitions of necessary concepts (semantic density: very high).
- include activities corresponding to experiences/problems/opportunities. Thus, we include problem statements (learning Resource Type: problem statement) in order for the Learner to be able to find the meaning behind concepts by “playing” (active experimentation with LOGOS tools).
- not include explanations, statements of how things should be done reading, watching. Thus, we don’t include manuals, video tutorials or walkthroughs of the LOGOS Tools.

Table 6.2 Training Method for Activists

LD AS/A #	Activity Structure/Activity Title	Properties	Best fit LO Title (to be selected at run time)
1	Introduction	lobv:describe LOGOS Project	
1a	The LOGOS Project	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define LOGOS Project	The LOGOS Project (semantic density:very high)
1b	The LOGOS Authoring Studio	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Authoring Studio	The LOGOS Authoring Studio (semantic density:very high)
2	Developing Ontologies	lobv: create Ontology	-
2a	What is an Ontology?	IRT: narrative text iT: expositive iL: medium sD: very high lobv: define Ontology	Ontologies (semantic density: very high)
2b	What is the Ontology Management Tool?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Ontology Management Tool -OMT	The Ontology Management Tool (semantic density: very high)
2c	Using Ontology Management Tool (OMT) to create and manage Ontologies – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Ontology Management Tool -OMT	Creating Ontologies using Ontology Management Tool (OMT) – Problem Statement
3	Developing Media Objects	lobv: create Media Object - MO	-
3a	What is a Media Object?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Media Object - MO	Media Objects (MOs) (semantic density: very high)
3b	What is the Media Server?	IRT: narrative text iT: expositive	The Media Server (semantic density: very

		iL: very low sD: very high lobv: define Media Server	high)
3c	Using Media Server to create and manage Media Objects	IRT: problem statement iT: active iL: very high sD: very high lobv: use Media Server	Creating Media Objects using Media Server – Problem Statement
4	Developing Digital Objects	lobv: create Digital Object - DO	-
4a	What is a Digital Object?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Digital Object - DO	Digital Objects (DOs) (semantic density: very high)
4b	What is the Content Description Tool?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Content Description Tool - CDT	The Content Description Tool (semantic density: very high)
4c	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Media Server	Creating Digital Objects using Content Description Tool (CDT) – Problem Statement
5	Developing Learning Objects	lobv: create Learning Object - LO	-
5a	What is a Learning Object?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Learning Object - LO	Learning Objects (LOs) (semantic density: very high)
5b	What is the Description Tool for Learning Objects?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Description Tool for Learning Objects - DTLO	The Description Tool for Learning Objects (semantic density: very high)
5c	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) – Problem Statement	IRT: problem statement iT: active iL: medium sD: very high lobv: use Description Tool for Learning Objects - DTLO	Creating Learning Objects using Description Tool for Learning Objects (DTLO) and other tools – Problem Statement
6	Developing Courseware Objects	lobv: create Courseware Object - CO	-
6a	What is a Courseware Object?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Courseware Object - CO	Courseware Objects (COs) (semantic density: very high)
6b	What is the Courseware Object Editor?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Courseware	The Courseware Objects Editor (semantic density: very high)

		Object Editor - COE	
6c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Courseware Object Editor - COE	Creating Courseware Objects using Courseware Objects Editor (COE) - Problem Statement
7	Developing Assessment Objects	lobv: create Assessment Object - AO	-
7a	What is an Assessment Object?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Assessment Object - AO	Assessment Objects (AOs) (semantic density: very high)
7b	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO	Creating Assessment Item Objects Using Description Tool for Learning Objects (DTLO) – Problem Statement
7c	Using Courseware Objects Editor (COE) to create and manage Assessment Test Objects (ATOs) – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE	Creating Assessment Tests Objects using Courseware Objects Editor (COE) – Problem Statement
8	Developing Learning Designs	lobv: create Learning Design	-
8a	What is a Learning Design?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Learning Design	Learning Designs (LDs) (semantic density: very high)
8b	What is the Learning Design Editor?	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Learning Design Editor – LDE	The Learning Designs Editor (semantic density: very high)
8c	Using Learning Designs Editor (LDE) to create and manage Learning Designs (LDs) – Problem Statement	IRT: problem statement iT: active iL: very high sD: very high lobv: use Learning Design Editor - LDE Semantics: Learning Design → developed with 6 → Learning Design Editor - LDE	Creating Learning Designs using Learning Designs Editor (LDE)

6.3.2.4.2 Training Method for Reflectors (Reflective Observation)

Reflectors learn best from activities where they are allowed or encouraged to watch/think/chew over activities. They are able to stand back from events and listen/observe (i.e., observing a group at work, taking a back seat in a meeting, watching a film or video). They like research and investigation. They learn least from, and may react against activities where they are involved in situations which require action without planning and when they are given insufficient data on which to base a conclusion. They like to read instructions, count pieces and think things through observation but they may react against given cut and dried instructions on how things should be done.

Consequently, a Training Method for Reflectors should:

- include activities where they can watch, observe things e.g. videos or simulations (learning Resource Type: simulation, interactivity type: expositive, interactivity level: low). Thus, Video Tutorials and Manuals are very appropriate for Reflectors.
- not include cut and dried instructions on how things should be done. Thus, Walkthroughs are not appropriate for Reflectors.
- include enough theory (sufficient data) but not too much as in the case of a Theorist (semantic density: medium).

Table 6.3 Training Method for Reflectors

LD AS/A #	Activity Structure/Activity Title	Properties	Best fit LO Title (to be selected at run time)
1	Introduction	lobv: describe LOGOS Project	-
1a	The LOGOS Project	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Project	The LOGOS Project (semantic density: medium)
1b	The LOGOS Platform	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Platform	The LOGOS Platform (semantic density: medium)
1c	LOGOS Objects	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe Object	LOGOS Objects (semantic density: medium)
1d	The LOGOS Authoring Studio	IRT: narrative text iT: expositive iL: very low sD: medium lobv: define Authoring Studio	The LOGOS Authoring Studio (semantic density: medium)
2	Developing Ontologies	lobv: create Ontology	-

2a	Using Ontology Management Tool (OMT) to create and manage Ontologies – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Ontology Management Tool -OMT	Ontology Management Tool (OMT) Tutorial
2b	Using Ontology Management Tool (OMT) to create and manage Ontologies – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Ontology Management Tool -OMT	Ontology Management Tool (OMT) User Manual
3	Developing Media Objects	lobv: create Media Object - MO	-
3a	Using Media Server to create and Manage Media Objects – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Media Server	N/A
3b	Using Media Server to create and manage Media Objects – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Media Server	Media Server User Manual
4	Developing Digital Objects	lobv: create Digital Object - DO	-
4a	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Media Server	Content Description Tool (CDT) Tutorial
4b	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Media Server	Content Description Tool (CDT) User Manual
5	Developing Learning Objects	lobv: create Learning Object - LO	-
5a	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Description Tool for Learning Objects – DTLO	Description Tool for Learning Objects (DTLO) Tutorial for Learning Objects (LOs)
5b	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Description Tool for Learning Objects - DTLO	Description Tool for Learning Objects (DTLO) User Manual
6	Developing Courseware Objects	lobv: create Courseware Object - CO	-
6a	Using Courseware Objects Editor to create and manage Courseware Objects (COs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Courseware Object Editor - COE	N/A
6b	Using Courseware Objects Editor to create and manage	IRT: narrative text iT: expositive	Courseware Object Editor (COE) User Manual

	Courseware Objects (COs) - Manual	iL: very low sD: very low lobv: use Courseware Object Editor - COE	
7	Developing Assessment Objects	lobv: create Assessment Object - AO	-
7a	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO → Tutorial	Description Tool for Learning Objects (DTLO) Tutorial for Assessment Item Objects (AIOs)
7b	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO → Manual	Description Tool for Learning Objects (DTLO) User Manual
7c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE → Tutorial	N/A
7d	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE → Manual	Courseware Objects Editor (COE) User Manual
8	Developing Learning Designs	lobv: create Learning Design	-
8a	Using Learning Designs Editor (LDE) to create and manage Learning Designs (LDs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Learning Design Editor - LDE Semantics: Learning Design → developed with 6 → Learning Design Editor - LDE	Learning Designs Editor (LDE) Tutorial
8b	Using Learning Designs Editor (LDE) to create and	IRT: narrative text iT: expositive	Learning Designs Editor (LDE) User Manual

	manage Learning Designs (LDs) - Manual	iL: very low sD: very low lobv: use Learning Design Editor - LDE Semantics: Learning Design →developed with 6 → Learning Design Editor – LDE	
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6.3.2.4.3 Training Method for Theorists (Abstract Conceptualization)

Theorists learn best from activities where what is being offered is part of a system, model, concept, theory. They like to have the time to explore methodically the associations and interrelationships between ideas, events and situations. They can listen to or read about ideas and concepts that emphasize rationality or logic and are well argued/elegant/watertight. They like structured situations with a clear purpose. They learn least from, and may react against activities where they are faced with a hotchpotch of alternative/contradictory techniques/methods without exploring any in depth (ie., as on a “once over lightly” course). They also learn least from activities where they doubt that the subject matter is methodologically sound. Moreover, they don’t like to study through application of knowledge.

Consequently, a Training Method for Theorists should:

- include activities where what is being offered is part of a system, model, concept, theory. Thus, theory coming from LOGOS deliverables and Manuals, where things are presented in this manner (systems, models, concepts and processes) is very appropriate after some adaptation.
- not include activities where they are forced to study through application of knowledge. Thus, problem statements for active experimentation and Walkthroughs are not very appropriate for Theorists.

Table 6.4 Training Method for Theorists

LD AS/A #	Activity Structure/Activity Title	Properties	Best fit LO Title (to be selected at run time)
1	Introduction	lobv: describe LOGOS Project	-
1a	The LOGOS Project	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe LOGOS Project	The LOGOS Project (semantic density: very low)
1b	The LOGOS Platform	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe LOGOS	The LOGOS Platform (semantic density: vlow)

		Platform	
1c	LOGOS Objects	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Object	LOGOS Objects (semantic density: very low)
2	Developing Ontologies	lobv: create Ontology	-
2a	Introduction to Ontologies	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Ontology	Ontologies (semantic density: very low)
2b	The Ontology Management Tool	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Ontology Management Tool -OMT	The Ontology Management Tool (semantic density: very low) Containing Ontology Management Tool DO and Process DO
2c	Using Ontology Management Tool (OMT) to create and manage Ontologies – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Ontology Management Tool -OMT	Ontology Management Tool (OMT) User Manual
3	Developing Media Objects	lobv: create	-
3a	Media Objects	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Media Object - MO	Media Objects (MOs) (semantic density: very low)
3b	The Media Server	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Media Server	The Media Server (semantic density: very low) Containing Media Server DO and Process MO
3c	Using Media Server to create and manage Media Objects - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Media Server	Media Server User Manual
4	Developing Digital Objects	lobv: create Digital Object - DO	-
4a	Digital Objects (DOs)	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Digital Object - DO	Digital Objects (DOs) (semantic density: very low)
4b	The Content Description Tool	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Content Description Tool - CDT	The Content Description Tool (semantic density: very low) Containing Content Description Tool (semantic density: very high) and Process DO

4c	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Media Server	Content Description Tool (CDT) User Manual
5	Developing Learning Objects	lobv: create Learning Object - LO	-
5a	Learning Objects (LOs)	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Digital Object - DO	Learning Objects (LOs) (semantic density: very low)
5b	The Description Tool for Learning Objects	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Description Tool for Learning Objects - DTLO	The Description Tool for Learning Objects (semantic density: very low) Containing The Description Tool for Learning Objects (semantic density: very high) and Process LO
5c	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Description Tool for Learning Objects - DTLO	Description Tool for Learning Objects (DTLO) User Manual
6	Developing Courseware Objects	lobv: create Courseware Object - CO	-
6a	Courseware Objects (COs)	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Courseware Object - CO	Courseware Objects (COs) (semantic density: very low)
6b	The Courseware Objects Editor	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Courseware Object Editor - COE	The Courseware Objects Editor (semantic density: very low) Containing The Courseware Objects Editor (semantic density: very high) and Process CO
6c	Using Courseware Objects Editor to create and manage Courseware Objects (COs) – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Courseware Object Editor - COE	Courseware Object Editor (COE) User Manual
7	Developing Assessment Objects	lobv: create Assessment Object - AO	-
7a	Assessment Objects (AOs)	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Assessment Object - AO	Assessment Objects (AOs) (semantic density: very low)
7b	Using Description Tool for	IRT: narrative text	Description Tool for

	Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Manual	iT: expositive iL: very low sD: very low lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO → Manual	Learning Objects (DTLO) User Manual
7c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) – Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE → Manual	Courseware Objects Editor (COE) User Manual
8	Developing Learning Designs	lobv: create Learning Design	-
8a	Learning Designs (LDs)	IRT: narrative text iT: expositive iL: very low sD: very high lobv: define Assessment Object - AO	Learning Designs (LDs) (semantic density: very low)
8b	The Learning Designs Editor	IRT: narrative text iT: expositive iL: very low sD: very low lobv: describe Learning Design Editor – LDE	The Learning Designs Editor (semantic density: very low) Containing The Learning Designs Editor (semantic density: very high) and Process LD
8c	Using Learning Designs Editor (LDE) to create and manage Learning Designs (LDs) - Manual	IRT: narrative text iT: expositive iL: very low sD: very low lobv: use Learning Design Editor - LDE Semantics: Learning Design → developed with 6 → Learning Design Editor – LDE	Learning Designs Editor (LDE) User Manual

6.3.2.4.4 Training Method for Pragmatists (Active Experimentation)

Pragmatists learn best from activities where there is an obvious link between the subject matter and the problem or opportunity on the job. They like activities where techniques for doing things with practical advantages are shown. They also learn best from activities where they are exposed to a model they can emulate, i.e., a demonstration from someone with a proven track record, lots of examples/anecdotes, a film showing how it's done. They like techniques currently applicable to their own job. Pragmatists like to work

actively on well-defined tasks and learn by trial and error. They like to have immediate opportunities to implement what they have learned. Pragmatists learn least from, and may react against activities where the learning is not related to an immediate need they recognize/they cannot see, an immediate relevance/practical benefit. They learn least when there is no practice or clear guidelines on how to do things.

Consequently, a Training Method for Pragmatists should:

- include activities that allow them to work actively on well-defined tasks and learn by trial and error. So, activities including experiments and Walkthroughs are appropriate.
- include activities where techniques for doing things with practical advantages are shown (demonstrations, examples). Thus, Video Tutorials are very appropriate in this case.

Table 6.5 Training Method for Pragmatists

LD AS/A #	Activity Structure/Activity Title	Properties	Best fit LO Title (to be selected at run time)
1	Introduction	lobv: describe LOGOS Project	-
1a	The LOGOS Project	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Project	The LOGOS Project (semantic density: medium)
1b	The LOGOS Platform	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Platform	The LOGOS Platform (semantic density: medium)
1c	LOGOS Objects	IRT: narrative text iT: expositive iL: very low sD: medium lobv: describe Object	LOGOS Objects (semantic density: medium)
1d	The LOGOS Authoring Studio	IRT: narrative text iT: expositive iL: very low sD: medium lobv: define Authoring Studio	The LOGOS Authoring Studio (semantic density: medium)
2	Developing Ontologies	lobv: create Ontology	-
2a	Using Ontology Management Tool (OMT) to create and manage Ontologies – Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Ontology Management Tool -OMT	Experimenting with CoGUI (from CoGUI site)
2b	Using Ontology Management Tool (OMT) to create and manage Ontologies – Tutorial	IRT: simulation iT: expositive iL: low sD: very low	Ontology Management Tool (OMT) Tutorial

		lobv: use Ontology Management Tool -OMT	
3	Developing Media Objects	lobv: create Media Object - MO	-
3a	Using Media Server to create and Manage Media Objects - Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Media Server	Media Server Cognitive Walkthrough
3b	Using Media Server to create and Manage Media Objects – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Media Server	N/A
4	Developing Digital Objects	lobv: create Digital Object - DO	-
4a	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) - Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Media Server	Content Description Tool (CDT) Cognitive Walkthrough
4b	Using Content Description Tool (CDT) to create and manage Digital Objects (DOs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Media Server	Content Description Tool (CDT) Tutorial
5	Developing Learning Objects	lobv: create Learning Object - LO	-
5a	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) - Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Description Tool for Learning Objects – DTLO	Description Tool for Learning Objects (DTLO) Walkthrough for Learning Objects (LOs)
5b	Using Description Tool for Learning Objects (DTLO) to create and manage Learning Objects (LOs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Description Tool for Learning Objects – DTLO	Description Tool for Learning Objects (DTLO) Tutorial for Learning Objects (LOs)
6	Developing Courseware Objects	lobv: create Courseware Object - CO	-
6a	Using Courseware Objects Editor to create and manage Courseware Objects (COs) - Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Courseware Object Editor - COE	N/A
6a	Using Courseware Objects Editor to create and manage Courseware Objects (COs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Courseware Object Editor - COE	N/A
7	Developing Assessment Objects	lobv: create Assessment Object - AO	-
7a	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects	IRT: experiment iT: active iL: very low sD: low	Description Tool for Learning Objects (DTLO) Walkthrough for Assessment Item Objects

	(AIOs) – Experiment	lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO	(AIOs)
7b	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO → developed with 1 → Description Tool for Learning Objects – DTLO → Tutorial	Description Tool for Learning Objects (DTLO) Tutorial for Assessment Item Objects (AIOs)
7c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) - Experiment	IRT: experiment iT: active iL: very low sD: low lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE	Courseware Objects Editor (COE) Cognitive Walkthrough
7d	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Courseware Object Editor – COE Semantics: Assessment Test Object – ATO → developed with 2 → Courseware Object Editor – COE → Tutorial	N/A
8	Developing Learning Designs	lobv: create Learning Design	-
8a	Using Learning Designs Editor (LDE) to create and manage Learning Designs (LDs) - Experiment	IRT: simulation iT: expositive iL: low sD: very low lobv: use Learning Design Editor - LDE Semantics: Learning Design → developed with 6 → Learning Design Editor - LDE	Learning Designs Editor (LDE) Cognitive Walkthrough
8b	Using Learning Designs Editor (LDE) to create and manage Learning Designs (LDs) - Tutorial	IRT: simulation iT: expositive iL: low sD: very low lobv: use Learning Design Editor - LDE Semantics: Learning Design → developed with 6 → Learning Design Editor - LDE	Learning Designs Editor (LDE) Tutorial

6.3.3. Experimental Results

According to a general picture, the assigned Abstract Tasks have been observed as carried out with no evident difficulty from both Authors and Learners using the LOGOS platform and tools [Corep, Eden, and UniBrighton, 2009]. Tested scenarios have been almost balanced among either Authors or Learners groups. Most Learners didn't perceive any difficulties in learning experience with the platform: this mitigate the more conservative vision from the Authors. Personalization advantages have been supported by both groups of experiment participants: about 31% of Authors and 42% of Learners (taking into account that 2/3 of the Authors and 45.5% of the Learners did not experience personalization).

6.3.3.1. Authors

Two third of the Authors did not experience the personalization feature, while almost all of those who applied it (30.77%), identified it as a very innovative practice (Figure 6.19).

Personalization



Figure 6.19 Authors' answers to the question "Were any innovative practices identified by users (personalization) [Y/N]"

Table 6.6 gathers Authors' assessment results to the questions related with personalization.

The authors explicitly expressed their satisfaction with the Learning Designs Editor (LDE) saying that in their opinion it was dealing with the most difficult feature of the LOGOS platform but yet it was quite user-friendly. The users outlined the the LDE as the most supporting tool, having in mind their excellent tutorials and the informative messages on the screen.

Table 6.6 Authors assessment

If you think the statement is true, then mark the column for “predominately agree”. If you find you cannot agree with the statement then mark column for “Predominately disagree”. You can also indicate various degrees of agreement between these two poles by marking the corresponding column. If for some reason you cannot or do not wish to reply, you should mark the last column “no opinion”.							
	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	No opinion	Response Count
I consider personalization applied by LOGOS as an innovative practice	2.3% (1)	2.3% (1)	2.3% (1)	9.1% (4)	50.0% (22)	34.1% (15)	44
I think personalized learning material provided by LOGOS improves a student’s learning outcomes	0.0% (0)	0.0% (0)	4.7% (2)	7.0% (3)	48.8% (21)	39.5% (17)	43
I think that learners accessing personalized materials would shorten their learning time	0.0% (0)	2.3% (1)	11.6% (5)	30.2% (13)	23.3% (10)	32.6% (14)	43
I think personalized learning material provided by LOGOS improves participation rates	0.0% (0)	0.0% (0)	7.0% (3)	9.3% (4)	41.9% (18)	41.9% (18)	43

6.3.3.2. Learners

54.5% of the Learners experienced personalization, while 45.5% of them selected a static course (Figure 6.20).

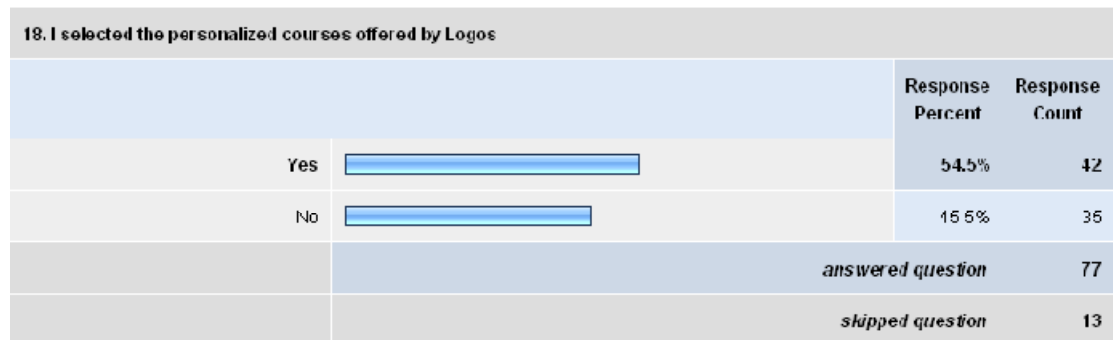


Figure 6.20 Learners that selected personalized courses vs. them that did not

35.48% of the Learners identified personalization as an innovative practice, as illustrated in Figure 6.21.

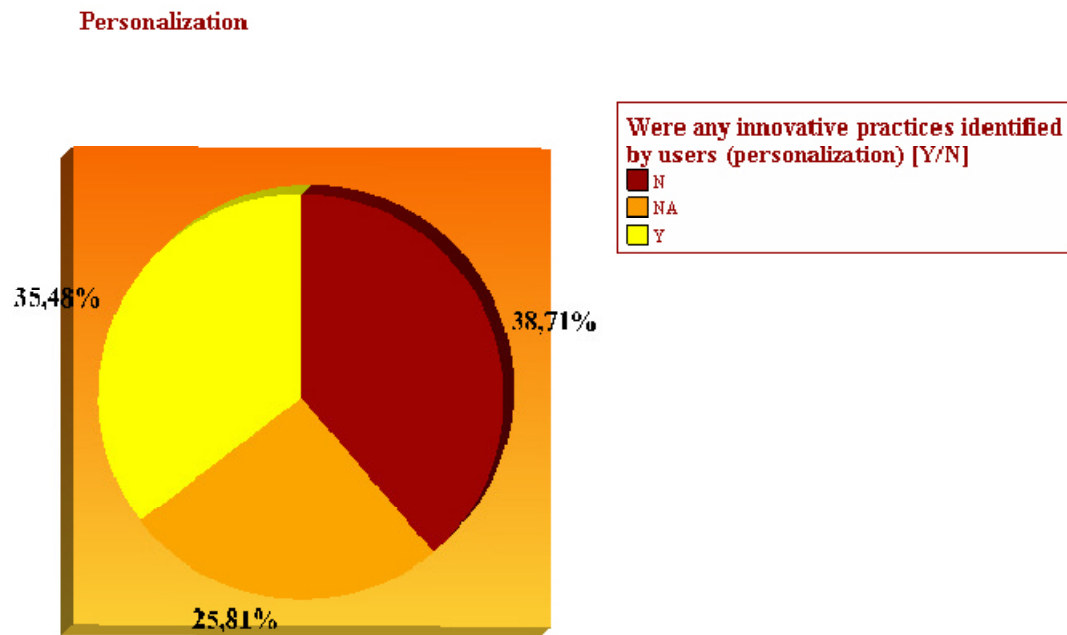


Figure 6.21 Learners' answers to the question "Were any innovative practices identified by users (personalization) [Y/N]"

The personalization exercise was met with enthusiasm. Unfortunately, one of the tested scenario ("Bulgarian Iconography") did not offer personalized courses that matched the learning style of the testers, thus its efficiency could not be tested. This also explains that some of the Learners, who experienced personalization with the "Bulgarian Iconography" scenario, are in those who answered "N" or "NA" to the question if there were any innovative practices identified by users (personalization).

All the users stated that they found the learning process with personalisation to be very motivating. All the Learners were excited about the personalisation feature although in the case of "Bulgarian Iconography" scenario there wasn't appropriate content available for every type of learning style. Personalization was found to improve their performance.

Table 6.7 gathers the Learners' assessment results to the questions related with personalization.

Table 6.7 Learners assessment

If you think the statement is true, then mark the column for "predominately agree". If you find you cannot agree with the statement then mark column for "Predominately disagree". You can also indicate various degrees of agreement between these two poles by marking the corresponding column. If for some reason you cannot or do not wish to reply, you should mark the last column "no opinion".							
	Strongly disagree	Slightly disagree	Neither agree nor disagree	Slightly agree	Strongly agree	No opinion	Response Count
Learning with personalized courses matched perfectly with my expectation	4.8% (2)	9.5% (4)	19.0% (8)	33.3% (4)	31.0% (13)	2.4% (1)	42

I found that it was motivating to learn with the personalized course	0.0% (0)	9.5% (4)	16.7% (7)	19.9% (8)	52.4% (22)	2.4% (1)	42
I think personalized learning materials provided by LOGOS improve a student's learning outcomes	1.4% (1)	2.8% (2)	13.9% (10)	18.1% (13)	51.4% (37)	12.5% (9)	72
In my opinion accessing personalized learning materials would shorten my learning time compared to face-to-face learning	4.2% (3)	12.5% (9)	13.9% (10)	27.8% (20)	30.6% (22)	11.1% (8)	72
I think personalized learning materials provided by LOGOS improve participation rates	1.4% (1)	2.8% (2)	16.7% (10)	16.7% (10)	47.2% (34)	15.3% (11)	72

6.4. Summary

In this chapter, the evaluation and experimentation of this thesis framework, as it has been performed in the context of the European projects DELOS and LOGOS, has been presented. The experiments have been shown a positive effect of the personalization in the learning efficiency, as well as a positive acceptance from the end users (Authors and Learners).

However, it should be noted here, that in order for the framework to work as expected, the methodology described in the previous chapters of this thesis should be applied. If not, then the personalization framework can not be successfully applied and the results of the evaluation may not be reliable and positive. To set and perform a reliable evaluation experiment we should among others ensure that:

- The Learning Designer is a domain expert
- The Learning Designer is an expert in pedagogical theories and approaches and more specifically is an expert on the specific learning style approach that will be applied in the formation of the learning processes in terms of learning designs
- The selected learning style approach itself is widely accepted and has been proved effective when applied in the formation of learning processes
- Domain knowledge has been appropriately represented as an ontology, taxonomy or concept map

- The Learning Objectives/Goals have been appropriately defined according to this framework, as pairs consisting of an educational verb from Bloom's taxonomy and a topic from the domain knowledge representation (ontology, taxonomy or concept map)
- The Learning Objects and Assessment Objects have been appropriately formulated in terms of their content and granularity, described and connected to Learning Objectives.

Chapter 7. CONCLUSIONS AND FUTURE WORK

7.1. Conclusions

ELearning applications are immensely more valuable when they can use the wealth of information that exists in multimedia digital libraries. Thus, it is crucial to bridge the interoperability gap between digital libraries and eLearning applications in order to enable the construction of eLearning applications that easily exploit digital library contents. This is a complex and multilevel problem. Towards this end, this thesis has proposed a framework and a service-oriented Architecture that Supports Interoperability of Digital Libraries with ELearning Applications (ASIDE). This framework goes beyond the domain of eLearning and is able to accommodate approaches that aim at repurposing and use the underlying digital library content in other domains as well such as eScience, eResearch etc. That means that this framework can be easily applied in other types of applications, since it supports multiple contexts and views of the digital objects of a digital library. Using the approach proposed in this framework, the construction of audiovisual learning objects is possible, containing information about their educational use through learning object metadata, while in parallel retaining their audiovisual characteristics described using audiovisual standards (e.g. MPEG7).

A challenging problem that this framework had to address was how these audiovisual learning objects are afterwards combined or organized in meaningful structures to create learning experiences that are delivered through LMSs to Learners to cover their individual needs. The provision of efficient personalization services to Learners beyond “one size fits all” solutions is considered as a necessity to cope with this problem and generally with the overwhelming amount of available learning material existing in Digital Libraries. For that reason the framework provides the necessary methodology, models and mechanisms for the dynamic creation of pedagogically-sound personalized learning experiences from (audiovisual) learning objects taking into account the variety of the Learners and their individual needs.

The framework and the architecture proposed in this thesis has been successfully implemented and evaluated in the context of two European projects, DELOS II and LOGOS.

In the following sections, the contribution of this thesis is described in more detail, as well as future directions.

7.2. Contribution of this thesis in research projects, research publications, diploma theses and standardization activities

The work presented in this thesis has been exploited in two European Projects, DELOS and LOGOS. In DELOS II Network of Excellence in Digital Libraries (IST – Project Record Number 507618) JPA2 subproject it was implemented in a service-oriented architecture above an experimental digital library of audiovisual content. Within the LOGOS Project “Knowledge-on-Demand for Ubiquitous Learning” (IST-4-027451), the framework and the architecture was adapted in order to design and implement a Knowledge-on-Demand ubiquitous learning platform, providing effective personalized learning services to support learning anywhere, anytime exploiting alternative delivery channels and related devices that go beyond the traditional web-based learning approaches.

Furthermore, parts of the work done in this thesis have been published in a number of peer reviewed conference publications as well as in a number of technical reports. Moreover, this thesis was the basis for three diploma theses in the Electronic and Computer Engineering Department of the Technical University of Crete.

Finally, the author of this thesis has been invited from the Greek Organization of Standardization (ELOT) to participate in eLearning standardization activities where as a member of the Working Group 3/Technical Committee 48 of ELOT is responsible for the subactivity related with interoperability of eLearning Applications with Digital Libraries and the support of eLearning personalization services on top of them.

These contributions are described in the following sections.

7.2.1. DELOS II Network of Excellence (IST – 507618) Project

DELOS is a Network of Excellence on Digital Libraries, partially funded by the European Commission’s Information Society Technologies Programme (IST). The main objective of DELOS is to coordinate a joint programme of activities of the major European teams working on digital library related areas.

The work presented in this thesis was the main subject of DELOS T5.4 JPA2 subproject, named “Interoperability of eLearning applications with digital libraries”.

DELOS Task T5.4 has sought to answer the following questions:

- What are the major architectural requirements and workflows for effectively supporting eLearning applications running on top of digital libraries?
- What are the major interoperability requirements for digital libraries standards and eLearning standards?

The proposed frameworks were initially developed and implemented in DELOS II Network of Excellence in Digital Libraries (IST – Project Record Number 507618) JPA2 subproject, named “Task 5.4 Interoperability of eLearning Applications with Digital Libraries” in a integrated service-oriented architecture above an experimental digital library of audiovisual content [Arapi, Moumoutzis, and Christodoulakis, 2006; Arapi et al., 2007b; Christodoulakis et al., 2006].

7.2.2. LOGOS “Knowledge-on-Demand for Ubiquitous Learning” (IST-4-027451) Project

LOGOS was an IST research project involving an interdisciplinary 15-member consortium from nine countries. The aim of the project was to create a platform for ubiquitous learning that combines the use of courseware objects from the LOGOS authoring studio with cross-media delivery through digital video broadcasting (DVB), mobile and IP-based communication channels.

This involved:

- Integrating a new cross-media platform for eLearning using current technologies of Internet, mobile phone and Digital Video Broadcasting (DVB).
- Generating the new cross-media learning context with specially developed authoring studios using existing archives.
- Validating a new eLearning platform by extended experimentation of its functionality and usability by end-users.

A big part of this project’s research proposal was based on the concepts developed in this thesis. Moreover, the implementation of a part of the LOGOS architecture has been based on the interoperability architecture and the personalization framework developed in this thesis [Arapi et al., 2007e; Moumoutzis, Arapi, and Stockinger, 2008].

7.2.3. Publications & Technical Reports

Several parts of the work presented in this thesis have been published in the following proceedings:

- Arapi P., Moumoutzis N., Mylonakis M., Stylianakis G., Theodorakis G., Christodoulakis S. (2008): “Design, Implementation and Experimental Evaluation of a Pedagogy-Driven Framework to Support Personalized Learning Experiences”, In the Proceedings of the 2nd LOGOS Open Workshop on “Cross-Media and Personalized Learning Applications with Intelligent Content” (LAIC 2008), September 2008, Varna, Bulgaria.

- Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Framework and an Architecture for Supporting Interoperability between Digital Libraries and eLearning Applications”, Book chapter in “Digital Libraries: Research and Development”, Lecture Notes in Computer Science, Springer Berlin/Heidelberg, Volume 4877/2007, pp. 137-146.
- Arapi P., Moumoutzis N., Mylonakis M., Theodorakis G., Stylianakis G. (2007): “Supporting Personalized Learning Experiences within the LOGOS Cross-Media Learning Platform”, In the Proceedings of the Workshop on Cross-Media and Personalized Learning Applications on top of Digital Libraries (LADL2007) in conj. with ECDL2007 Conference, September 2007, Budapest, Hungary.
- Arapi P., Moumoutzis N., Mylonakis M., Theodorakis G., Christodoulakis S. (2007): “A Pedagogy-driven Personalization Framework to Support Automatic Construction of Adaptive Learning Experiences”, In the Proceedings of the 6th International Conference on Web-based Learning (ICWL 2007), August 2007, Edinburgh, United Kingdom.
- Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Pedagogy-driven Personalization Framework to Support Adaptive Learning Experiences”, In the Proceedings of the 7th IEEE International Conference on Advanced Learning Technologies (ICALT 2007), July 2007, Niigata, Japan.
- Arapi P., Moumoutzis N., Mylonakis M., Christodoulakis S. (2007): “A Framework and an Architecture for Supporting Interoperability between Digital Libraries and eLearning Applications”, In the Proceedings of the DELOS Conference on Digital Libraries, February 2007, Tirrenia, Pisa, Italy.
- Christodoulakis S., Arapi P., Moumoutzis N., Mylonakis M., Patel M., Kapidakis S., Papatheodorou C., Arahova A., Vagiati B., Konsolaki H. (2006): “Interoperability of eLearning Applications with Digital Libraries”, In the Proceedings of the 10th European Conference on Research and Advanced Technology for Digital Libraries (ECDL 2006), September 2006, Alicante, Spain.
- Arapi P., Moumoutzis N., Christodoulakis S. (2006): “ASIDE: An Architecture for Supporting Interoperability between Digital Libraries and ELearning Applications”, In the Proceedings of the 6th IEEE International Conference on Advanced Learning Technologies (ICALT 2006), July 2006, Kerkrade, The Netherlands.
- Christodoulakis S., Arapi P., Moumoutzis N., Patel M., Kapidakis S., Arahova A., Bountouri L. (2005): “Interoperability of eLearning Applications with Audiovisual Digital Libraries”, In the Proceedings of the 9th European

Conference on Research and Advanced Technology for Digital Libraries (ECDL 2005), September 2005, Vienna, Austria.

Moreover, several parts of this work have been included in the following technical reports of DELOS and LOGOS projects:

- Christodoulakis S., Arapi P., Mylonakis M., Moumoutzis N., Patel M., Kapidakis S., Vagiati V., and Konsolaki H.(2006): “D5.4.2 - Demonstrator of mapping between the eLearning and AV content description standards”, Deliverable, DELOS Project, Submission date: 25/07/2006.
- Lyon L., Patel M., Christodoulakis S., Arapi P., Moumoutzis N., Kapidakis S., Doerr M., Iorizzo D., and Tudhope D. (2006): “D5.0.2 - Status report for Work Package 5”, Deliverable, DELOS Network of Excellence, Submission date: 12/09/2006.
- Pemberton L., Arapi P., Moumoutzis N., Horváth Z., Markus Z. (2007): “Report on Work Package 2: Modelling of Cross-Media Learning Processes and Platform Architecture for Ubiquitous Learning”, Deliverable D3, LOGOS Project, Submission date: 30/04/2007.
- Moumoutzis N., Arapi P., Stockinger P. (Eds.) (2008): “D6 - Report on work package WP3: LOGOS subsystem for transforming digitised knowledge in courseware objects”, Deliverable D6, LOGOS Project, Submission date: 28/01/2008.
- Arapi P., Moumoutzis M., Horváth Z. (2009): “Report on task T5.4: Enhancement of the LOGOS platform functionality”, Deliverable D11, LOGOS Project, Submission date: 26/02/2009.

7.2.4. Diploma theses based on this work

This work represented the basis for three diploma theses in the Laboratory of Distributed Multimedia Systems and Applications of the Electronic and Computer Engineering Department of the Technical University of Crete, which I personally supervised:

- Mylonakis M. (2008): “Development of a system for the provision of personalized learning experiences on top of audiovisual digital libraries”, Diploma Work, Department of Electronic and Computer Engineering, Technical University of Crete, Chania, 2008.
- Stylianakis G. (2008): “Design and Development of a Repository for Educational, Learning and Evaluation objects based on the METS Digital Library Model”,

Diploma Work, Department of Electronic and Computer Engineering, Technical University of Crete, Chania, 2008.

- Theodorakis G. (2007): “Design and Development of LEARNING DESIGN EDITOR: A Tool for managing abstract learning scenarios”, Diploma Work, Department of Electronic and Computer Engineering, Technical University of Crete, Chania, 2007.

At this point, let me emphasise again that I am indebted to these students (some of them are currently colleagues of my) for their contributions to the implementation of several parts of this framework.

7.2.5. Participation in standarization activities through membership in Greek Organization for Standarization (ELOT)

Ms. Arapi is a member of the Working Group 3/Technical Committee 48 of the Greek Organization for Standardization (ELOT) working in the area of learning processes and technologies standardization. Through ELOT she is also a member of the corresponding Working Groups ISO/IEC JTC1 SC36, CEN/ TC 353 and CEN/ISSS WSLT. Currently, the main activities of the Working Group 3 of ELOT are focusing on:

- Learning Object Metadata & Repositories,
- Digital Content Libraries, and
- Learner Mobility Information

The author of this thesis is coordinating the second activity dealing with the problem of interoperability of eLearning Applications with Digital Libraries in order to be able to exploit the wealth of content residing in them.

7.3. Future Work

In the future we intend to support authors in the process of the creation of learning design with the use of meta-templates. Moreover, we intend to apply and adapt part of the work done in this thesis in the context of a new project that deals with the problem of supporting effective eLearning applications on top of Natural History Museums' digital libraries and their integration with the European Digital Library (Europeana).

7.3.1. Guided creation of Learning Designs to support several learning style approaches

From the personalization framework evaluation results it was revealed that authors faced difficulty in the development of learning designs to support specific learning style approaches. That occurs because developing instructional strategies to support specific learning styles requires special pedagogical skills and authors rarely have this pedagogical

background. Depending on the selected learning style approach authors can be supported in the learning designs creation through the Learning Designs Editor with the use of meta-templates that will provide guidance on which type of activities should be included in order to support a specific learning style, how they should be organized and which type of content may be appropriate to be associated with them. So, a possible extension of the Learning Designs Editor would be a module able to interpret those meta-templates and use them for the guidance of authors in the implementation of learning designs.

7.3.2. Application of the frameworks developed in this thesis in the CIP PSP Natural Europe project

In an era where natural history and environmental education inadequacy in formal and informal contexts is becoming an increasingly challenging issue, harvesting the potential of European digital libraries appears as a very attractive option. However, an impressive abundance of high quality digital content that is available in Natural History Museums around Europe remains largely unexploited due to a number of barriers, such as: the lack of interconnection and interoperability between the management systems of Natural History Museums, the lack of centralised access through a European point of reference like Europeana, as well as the inefficiency of current content organization and the metadata used.

A major problem is however the lack of effective support of digital library applications like learning. Applications are well known to be long living, and typically they have longer life than systems. Thus they tend to create their own standards and support infrastructures based on those standards. These independent infrastructures and applications however do not exploit the vast wealth of information in the European digital libraries, and they do not interoperate effectively and efficiently with them.

The Natural Europe project suggests a coordinated solution at European level in order to overcome the aforementioned barriers. More specifically, Natural Europe aims to deliver the following services/solutions:

- connect the digital collections of European Natural History Museums with Europeana, helping them overcome obstacles such as the lack of interoperable systems and metadata;
- study the educational methods and deploy the necessary software tools that will allow educators to design innovative online pathways through the digital collections of Natural History Museums;
- facilitate the storage, search and retrieval of learning objects from Europeana according to international learning standards;

- facilitate the search and retrieval from Europeana of digital library objects related to educational profiles, objectives and curricula on Natural History, Environmental Education, and Biological Sciences;
- facilitate existing educational search software to interface with the Europeana digital library;
- design and deploy novel graphical interfaces that will facilitate the navigation of educational pathways within digital collections, both from Europeana and the Museum's Web sites;
- adapt and test innovative interactive installations at the Natural History Museums that will allow visitors to follow educational pathways through Europeana's content on Natural History and Sciences, as part of the Museums' exhibition;
- evaluate and validate the delivered services/solutions through extensive pilot trials with project-internal and external organisations and user groups.

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Appendix 1: Semantic mapping between MPEG7 and LOM

MPEG7	MPEG7 Definition	LOM#	LOM	LOM Definition
MediaInformation.MediaIdentification.EntityIdentifier	Identifies uniquely the particular and unique multimedia and content entity (e.g. ISOs, ISAN).	1.1	general.identifier	Globally unique label for learning object.
MediaInformation.MediaIdentification.EntityIdentifier.UniqueID [@type]	Describes the type of the identifier (e.g., URI, ISAN, ISWC, UMID, UPID). If no value is specified, the identifier is assumed to be a URI.	1.1.1	general.identifier.catalog	Represents the name or designator of the identification or cataloging scheme for the entry. There are a variety of cataloging systems available (e.g. URI, URN, DOI etc.).
MediaInformation.MediaIdentification.EntityIdentifier.UniqueID	Describes the unique identification of a resource. An instance of this datatype contains a value (an identifier) that allows some resource to be identified. The identifying value can be either a textual or a binary value that is encoded in base16 or base 64 format.	1.1.2	general.identifier.entry	The value of the identifier within the identification or cataloging scheme that designates or identifies this learning object. A namespace specific string.
CreationInformation.Creation.Title	Describes one textual title of the multimedia content. Multiple titles are allowed. They may correspond to different types (indicated by the type attribute) or to different languages (indicated by the xml:lang attribute).	1.2	general.title	Learning Object's name.
CreationInformation.Classification.Language	Describes the language of the spoken audio of the program.	1.3	general.language	Learning object's language.
CreationInformation.Creation.Abstract	Describes a textual abstract of the multimedia content (optional). It is a summary, assigned during the creation process, of what is conveyed in the multimedia content.	1.4	general.description	Describes learning object's content.

DescriptionMetadata.Comment.FreeTextAnnotation	Describes a free text annotation.			
CreationInformation.Classification.Genre.Name	Describes what the multimedia content is about (broad classification).	1.5	general.keyword	Keywords describing the resource.
DescriptionMetadata.Comment.TextAnnotation.KeywordAnnotation	Describes a keyword annotation.			
CreationInformation.Classification.Target	Describes the target of the multimedia content in terms of market classification, age and country or region.	1.6	general.coverage	Temporal / spatial characteristics of content. Specifically, used to describe the time, culture, geography or region to which the SCORM Content Model Component applies.
CreationInformation.Classification.Region	Describes one target country or region for the multimedia content.			
CreationInformation.Creation.CreationCoordinates.Location	Describes the place where the multimedia content was created (optional).			
CreationInformation.Creation.CreationCoordinates.Date	Describes the date or period when the multimedia content was created (optional).			
DescriptionMetadata.Comment.StructuredAnnotation (When, Where, Who)	The StructuredAnnotation datatype represents an annotation structured in terms of actions, animate object (people and animals), objects, action, places, time, purposes, and manner.			
-	-	1.7	general.structure	Describes the underlying organizational structure of the SCORM Content Model Component. (e.g. atomic, collection, networked etc.).
-	-	1.8	general.aggregationLevel	Describes the functional granularity of the learning object.
DescriptionMetadata.Version	Specifies the version of the description to which the description metadata is attached (optional). The format for the version information is application dependent.	2.1	lifeCycle.version	The edition of this learning object.

CreationInformation.Creation.Creator (role= "creator")	Describes one creator of the multimedia content (persons, organizations, groups...).	2.3.1	lifecycle.contribute.role	Kind of contribution.
DescriptionMetadata.Creator	Describes a creator of the description to which the description metadata is attached (optional).	2.3.2	lifecycle.contribute.entity	Entity or entities involved, most relevant first.
CreationInformation.Creation.Date	Describes the date or period when the multimedia content was created.	2.3.3	lifecycle.contribute.date	Date of contribution.
DescriptionMetadata.PublicIdentifier	Identifies the description to which the description metadata is attached using a public, globally unique identifier (optional).	3.1	meta-Metadata.identifier	A globally unique label that identifies this metadata record.
DescriptionMetadata.PrivateIdentifier	Identifies the description to which the description metadata is attached using a private, application dependent identifier (optional). The format of this identifier is application defined and need not be unique. Multiple private identifiers may be associated with a description.			
DescriptionMetadata.PublicIdentifier[@type]	Describes the type of the identifier (e.g., URI, ISAN, ISWC, UMID, UPID). If no value is specified, the identifier is assumed to be a URI.	3.1.1	meta-Metadata.identifier.catalog	The name or designator of the identification or cataloguing scheme for this entry. A namespace scheme.
DescriptionMetadata.PublicIdentifier	Describes the unique identification of a resource.	3.1.2	meta-Metadata.Identifier.entry	The value of the identifier within the identification.
DescriptionMetadata.Creator	Describes a creator of the description to which the description metadata is attached (optional). This can be a person, organization, or the software application that automatically generated the metadata. Multiple creators are allowed if the metadata was created as the result of several creators cooperating.	3.2.2	meta-Metadata.contribute.entity	The identification of and information about entities contributing to this metadata instance.
DescriptionMetadata.CreationTime.timePoint	Describes the time when the description to which the description metadata is attached was created (optional).	3.2.3	meta-Metadata.contribute.date.dateTime	The date of the contribution.

MediaInformation.MediaProfile.MediaFormat.FileFormat	Describes the file format of the media profile.	4.1	technical.format	Technical data type of the resource.
MediaInformation.MediaProfile.MediaFormat.FileSize	Indicates the size, in bytes, of the file where the media profile is stored.	4.2	technical.size	The size of the digital resource in bytes. Only the digits '0' — '9' should be used; the unit is bytes, not Mbytes, GB, etc.
MediaLocator.MediaURI	Describes the location of external media data (optional).	4.3	technical.location	A string that is used to access this learning object. It may be a location (URL), or a method that resolves to a location (URI).
MediaInformation.MediaProfile.MediaFormat.System	Describes the broad media format of the media profile.	4.4	technical.requirement	The technology required to use this learning object, e.g. hardware, software, network, etc.
MediaInformation.MediaProfile.MediaFormat.System (value taken from the corresponding Classification Scheme)	Describes the broad media format of the media profile.	4.4.1.1	technical.requirement.orComposite.type.value	The technology required to use this learning object, e.g. hardware, software, network, etc.
MediaInformation.MediaProfile.MediaFormat.System (value taken from the corresponding Classification Scheme)	Describes the broad media format of the media profile.	4.4.1.2	technical.requirement.orComposite.name.value	Name of the required technology to use this learning object.
-	-	4.5	technical.installationRemarks	Description of how to install this learning object.
MediaTime.MediaDuration	Describes the duration of a media time period according to days and day time (optional).	4.7	technical.duration	Time a continuous learning object takes when played at intended speed.
CreationInformation.Classification.Purpose	Describes one purpose for which the multimedia content was created (optional). An example of CS is IntentionCS.	5.5	educational.intendedEndUserRole	Principal user(s) for which this learning object was designed, most dominant first.
CreationInformation.Classification.Age	Describes the targeted age range of the multimedia content (optional).	5.7	educational.typicalAgeRange	Age of the typical intended user.

UsageInformation.Rights	Describes information about the owners of the rights corresponding to the multimedia content, and how the multimedia content can be used (optional). Its appearance at this level precludes its appearance in the Availability DS instance of the same UsageInformation instance.	6	rights	This category describes the intellectual property rights and conditions of use for this learning object.
DescriptionMetadata.Rights	Describes the rights associated with the description to which the description metadata is attached and how the description to which this DS is attached can be used.			
UsageInformation.Availability.Rights	Describes information about the owners of the rights corresponding to the multimedia content, and how the multimedia content can be used (optional).			
UsageInformation.Availability.Financial	Describes the financial information related to the particular use described in the Availability description (optional).	6.1	rights.cost	Whether use of this learning object requires payment.
CreationInformation.Creation.CopyrightString	Describes one textual label indicating information that may be displayed or otherwise made known to the end user (optional). It is not a formal declaration of the usage rights of the multimedia content.	6.2	rights.copyrightAndOtherRestrictions	Whether copyright or other restrictions apply to the use of this learning object.
DescriptionMetadata.Rights.TextAnnotation.FreeTextAnnotation	Describes the rights associated with the description to which the description metadata is attached and how the description to which this DS is attached can be used. (These rights are described with free text annotation).	6.3	rights.description.string	Comments on the conditions of use of this learning object.
Segment.Relation	Describes a relation that the segment participates in (optional). The relations include structural relations defined in 11.10 and possibly other relations.	7	relation	This category defines the relationship between this learning object and other learning objects, if any.
DescriptionMetadata.Comment.TextAnnotation.FreeTextAnnotation	Describes a free text annotation.	8	annotation	Comments on the educational use of this learning object.

DescriptionMetadata.Creator.Agent.Person.Name	Describes an agent (abstract). The agent can be a person, a group of persons, or an organization. (This definition is for the AgentType).	8.1	annotation.entity	Entity that created this annotation (person, organization).
DescriptionMetadata.Creator.Agent.Organization.Name	Describes an agent (abstract). The agent can be a person, a group of persons, or an organization. (This definition is for the AgentType).			
DescriptionMetadata.Comment.StructuredAnnotation.Who	Describes animate objects or beings (people and animals) or legal persons (organizations and person groups) using either free text or a term from a classification scheme.			
DescriptionMetadata.CreationTime.TimePoint	Describes the time when the description to which the description metadata is attached was created (optional).	8.2	annotation.date.date Time	Date that this annotation was created.
DescriptionMetadata.Comment.StructuredAnnotation.When	Describes a time using either free text or a term from a classification scheme.			
DescriptionMetadata.Comment.TextAnnotation.FreeTextAnnotation	Describes a free text annotation.	8.3	annotation.description	The content of this annotation.
CreationInformation.Classification	Describes user oriented and service oriented classification of the multimedia content (optional).	9	classification	This category describes where this learning object falls within a particular classification system.
CreationInformation.Classification.Purpose	Describes one purpose for which the multimedia content was created (optional). An example of CS is IntentionCS.	9.1	classification.purpose	The purpose of classifying this learning object.
CreationInformation.Classification.Genre	Describes what the multimedia content is about (broad classification), such as sports, politics, economics, etc (optional). An example of CS is the GenreCS.	9.2.2	classification.taxon	A particular term within a taxonomy. A taxon is a node that has a defined label or term. A taxon may also have an alphanumeric designation or identifier for standardized reference. Either or both the label and the entry may be used to designate a particular taxon.

CreationInformation.Classification.Subject.TextAnnotation.FreeTextAnnotation	Describes the subject (specific classification) of the multimedia content (optional). The subject allows a textual annotation to classify the multimedia content.	9.3	classification.description	Description of the learning object relative to the stated 9.1:Classification.Purpose of this specific classification, such as discipline, idea, skill level, educational objective, etc.
CreationInformation.Classification.Subject.TextAnnotation.KeywordAnnotation.Keyword	Describes one keyword. A keyword can be a single word or an entire phrase made up of multiple words. For example, "President of the United States" can be treated as a keyword.	9.4	classification.keyword	Keywords and phrases descriptive of the learning object relative to the stated 9.1:Classification.Purpose of this specific classification, such as accessibility, security level, etc., most relevant first.

Appendix 2: Instructional Model in OWL and XML Schema

A2.1 Instructional Model in OWL

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<?xml version="1.0"?>

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  <!ENTITY xml "http://www.w3.org/XML/1998/namespace" >
  <!ENTITY rdfs "http://www.w3.org/2000/01/rdf-schema#" >
  <!ENTITY rdf "http://www.w3.org/1999/02/22-rdf-syntax-ns#" >
]>

<Ontology xmlns="http://www.w3.org/2002/07/owl#"
  xml:base="http://www.owl-ontologies.com/unnamed.owl"
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  xmlns:xml="http://www.w3.org/XML/1998/namespace"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
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    </DataPropertyAssertion>
    <DataPropertyAssertion>
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      <NamedIndividual IRI="#PrincipleOriented"/>
      <Literal datatypeIRI="&xsd:string">PrincipleOriented</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
      <DataProperty IRI="#educationallevel_taxonomy"/>
      <NamedIndividual IRI="#Secondary"/>
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.owl</Literal>
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    <DataPropertyAssertion>
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      <NamedIndividual IRI="#Secondary"/>
      <Literal datatypeIRI="&xsd:string">3</Literal>
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    <DataPropertyAssertion>
      <DataProperty IRI="#learningstyle_taxonomy"/>
      <NamedIndividual IRI="#SpecificToGeneral"/>
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datatypeIRI="&xsd:string">http://localhost:8080/ontologies/learningstyles1.o
wl</Literal>
    </DataPropertyAssertion>
    <DataPropertyAssertion>
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      <NamedIndividual IRI="#SpecificToGeneral"/>
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    </FunctionalObjectProperty>
    <FunctionalObjectProperty>
      <ObjectProperty IRI="#hasALearningObjective"/>
    </FunctionalObjectProperty>
    <FunctionalObjectProperty>
      <ObjectProperty IRI="#hasASLearningObjective"/>
    </FunctionalObjectProperty>
    <FunctionalObjectProperty>
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      <ObjectProperty IRI="#hasNextActivity"/>
    </FunctionalObjectProperty>
    <FunctionalObjectProperty>
      <ObjectProperty IRI="#hasNextActivityStructure"/>
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    <FunctionalObjectProperty>
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```

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  <ObjectProperty IRI="#semantics"/>
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  <Class IRI="#Activity"/>
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  <Class IRI="#ActivityStructure"/>
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```

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  <ObjectPropertyDomain>
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  <ObjectPropertyDomain>
    <ObjectProperty IRI="#requiresEducationalLevel"/>
    <Class IRI="#TrainingMethod"/>
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  <ObjectPropertyDomain>
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    <Class IRI="#DomainConcept"/>
  </ObjectPropertyDomain>
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    <Class IRI="#LearningObjectType"/>
  </ObjectPropertyRange>
  <ObjectPropertyRange>
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    <Class IRI="#Planner"/>
  </ObjectPropertyRange>
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    <Class IRI="#LearningStyle"/>
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    <ObjectProperty IRI="#hasNextActivity"/>
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</FunctionalDataProperty>
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</FunctionalDataProperty>
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    <DataProperty IRI="#educationallevel_value"/>
</FunctionalDataProperty>
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    <DataProperty IRI="#learning_objective_annotation"/>
</FunctionalDataProperty>
<FunctionalDataProperty>
    <DataProperty IRI="#learning_objective_verb"/>
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</FunctionalDataProperty>
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</FunctionalDataProperty>
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    <DataProperty IRI="#lom_difficulty"/>
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<FunctionalDataProperty>
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    <Class IRI="#LearningObjectType"/>
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  <DataPropertyDomain>
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    <DataProperty IRI="#email"/>
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    <Datatype abbreviatedIRI="xsd:string"/>
  </DataPropertyRange>
  <DataPropertyRange>
    <DataProperty IRI="#learning_objective_verb"/>
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      <Literal datatypeIRI="&xsd:string">access</Literal>
      <Literal datatypeIRI="&xsd:string">communicate</Literal>
      <Literal datatypeIRI="&xsd:string">compare and
contrast</Literal>
      <Literal datatypeIRI="&xsd:string">correlate</Literal>
      <Literal datatypeIRI="&xsd:string">criticise</Literal>
      <Literal datatypeIRI="&xsd:string">decide</Literal>
      <Literal datatypeIRI="&xsd:string">define</Literal>
      <Literal datatypeIRI="&xsd:string">describe</Literal>
      <Literal datatypeIRI="&xsd:string">determine</Literal>
      <Literal datatypeIRI="&xsd:string">differentiate</Literal>
      <Literal datatypeIRI="&xsd:string">discuss</Literal>
      <Literal datatypeIRI="&xsd:string">distinguish</Literal>
      <Literal datatypeIRI="&xsd:string">explain</Literal>
      <Literal datatypeIRI="&xsd:string">illustrate</Literal>
      <Literal datatypeIRI="&xsd:string">implement</Literal>
      <Literal datatypeIRI="&xsd:string">interpret</Literal>
      <Literal datatypeIRI="&xsd:string">label</Literal>
      <Literal datatypeIRI="&xsd:string">list</Literal>
      <Literal datatypeIRI="&xsd:string">predict</Literal>
      <Literal datatypeIRI="&xsd:string">recognise</Literal>
      <Literal datatypeIRI="&xsd:string">report</Literal>
      <Literal datatypeIRI="&xsd:string">reproduce</Literal>
      <Literal datatypeIRI="&xsd:string">show</Literal>
      <Literal datatypeIRI="&xsd:string">solve</Literal>
      <Literal datatypeIRI="&xsd:string">summarize</Literal>
      <Literal datatypeIRI="&xsd:string">teach</Literal>
      <Literal datatypeIRI="&xsd:string">understand</Literal>
      <Literal datatypeIRI="&xsd:string">use</Literal>
    </DataOneOf>
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  <DataPropertyRange>
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    <Datatype abbreviatedIRI="xsd:string"/>
  </DataPropertyRange>
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    <Datatype abbreviatedIRI="xsd:string"/>
  </DataPropertyRange>
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    <DataOneOf>
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      <Literal datatypeIRI="&xsd:string">easy</Literal>
      <Literal datatypeIRI="&xsd:string">medium</Literal>
      <Literal datatypeIRI="&xsd:string">very difficult</Literal>
      <Literal datatypeIRI="&xsd:string">very easy</Literal>
    </DataOneOf>
  </DataPropertyRange>

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  <DataOneOf>
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    <Literal datatypeIRI="&xsd:string">low</Literal>
    <Literal datatypeIRI="&xsd:string">medium</Literal>
    <Literal datatypeIRI="&xsd:string">very high</Literal>
    <Literal datatypeIRI="&xsd:string">very low</Literal>
  </DataOneOf>
</DataPropertyRange>
<DataPropertyRange>
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  <DataOneOf>
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    <Literal datatypeIRI="&xsd:string">expositive</Literal>
    <Literal datatypeIRI="&xsd:string">mixed</Literal>
  </DataOneOf>
</DataPropertyRange>
<DataPropertyRange>
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  <DataOneOf>
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    <Literal datatypeIRI="&xsd:string">exam</Literal>
    <Literal datatypeIRI="&xsd:string">exercise</Literal>
    <Literal datatypeIRI="&xsd:string">experiment</Literal>
    <Literal datatypeIRI="&xsd:string">figure</Literal>
    <Literal datatypeIRI="&xsd:string">graph</Literal>
    <Literal datatypeIRI="&xsd:string">index</Literal>
    <Literal datatypeIRI="&xsd:string">lecture</Literal>
    <Literal datatypeIRI="&xsd:string">narrative text</Literal>
    <Literal datatypeIRI="&xsd:string">problem statement</Literal>
    <Literal datatypeIRI="&xsd:string">questionnaire</Literal>
    <Literal datatypeIRI="&xsd:string">self assessment</Literal>
    <Literal datatypeIRI="&xsd:string">simulation</Literal>
    <Literal datatypeIRI="&xsd:string">slide</Literal>
    <Literal datatypeIRI="&xsd:string">table</Literal>
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</DataPropertyRange>
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    <Literal datatypeIRI="&xsd:string">sequence</Literal>
  </DataOneOf>
</DataPropertyRange>
<DataPropertyRange>
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  <DataProperty IRI="#value"/>

```

```

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  </DataPropertyRange>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#Activity</IRI>
    <Literal datatypeIRI="&xsd:string">Class taken from IMS Learning
Design Specification.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#ActivityStructure</IRI>
    <Literal datatypeIRI="&xsd:string">Class taken from IMS Learning
Design Specification. An ActivityStructure contains either simple Activities
or other ActivityStructures. Referencing other ActivityStructures means that
you can form an arbitrarily complex structure of activities. Typically, this
forms a tree hierarchy, but other types of structure are also
possible.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#DomainConcept</IRI>
    <Literal datatypeIRI="&xsd:string">Concepts or individuals from a
Domain Ontology that are related with a Learning Object. Domain Ontology and
Context Ontology (used to create LearningObjectives) could be different. For
example, a video that is Chemistry-related (Domain Ontology) can be used for
teaching Biology (Context Ontology). In the case that Domain ontology and
Context Ontology are the same (e.g. football) someone can use DomainConcept
to specify individuals (preferences). For example, we can have an Activity
that has Learning Objective "illustrate" "Drill" that is
related with "http://...owl#Ronaldo", meaning that from the
retrieved LOs with this Learning Objective we prefer those that are related
with Ronaldo Player.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#EducationalLevel</IRI>
    <Literal datatypeIRI="&xsd:string">The minimum EducationalLevel of a
Learner required to attend a TrainingMethod.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#LearningObjectType</IRI>
    <Literal datatypeIRI="&xsd:string">Used to describe the desired
Learning Object characteristics (requirements) without binding specific
objects with Activities on design time.
If more than one entries (LOTs) are used per Activity, the interpretation is
"OR".</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#LearningObjective</IRI>
    <Literal datatypeIRI="&xsd:string">Each Training, ActivityStructure
and Activity has a LearningObjective. Learning Objectives are treated here
in a more formal way than pure text descriptions, as in SeLeNe project
(Keenoy, K., Levene, M. & Peterson, D., 2004).

```

A separate entry for each objective.

Match with LearningObjectives of the T5.4 Learner Information Model and with

educational objectives of the LO descriptions (see Content Packaging report) using the classification element of LOM.

```

</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#LearningStyle</IRI>
    <Literal datatypeIRI="&xsd:string">There are several categorizations
of Learning Styles (see T5.4 report about Learning Styles (Konsolaki, C.,
Kapidakis, S. & Arapi, P., 2005). Thus, each LearningStyle has a
learningstyle_taxonomy property that is used to give the URL of the selected
taxonomy and a learningstyle_value indicating the Learning Style. This value
is taken by the taxonomy defined in the learningstyle_taxonomy property.
</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#Planner</IRI>
    <Literal datatypeIRI="&xsd:string">The creator of the
Training.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#Training</IRI>
    <Literal datatypeIRI="&xsd:string">A collection of abstract training
scenarios regarding one domain. The same subject can be taught in several
ways (Training Methods) depending on the Learning Style and the Educational
Level of the Learner.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#TrainingMethod</IRI>
    <Literal datatypeIRI="&xsd:string">A possible way (abstract training
scenario) to teach a specific subject. It consists of a hierarchy of
Activities. Different Training Methods can be developed for different
Learning Styles and Educational Levels.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#educationallevel_taxonomy</IRI>
    <Literal datatypeIRI="&xsd:string">The URL of the taxonomy used to
define educational levels</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#educationallevel_value</IRI>
    <Literal datatypeIRI="&xsd:string">The value of the EducationalLevel
specified in the taxonomy given in educationallevel_taxonomy.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#hasActivity</IRI>
    <Literal datatypeIRI="&xsd:string">Alternative activity</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#learning_objective_annotation</IRI>
    <Literal datatypeIRI="&xsd:string">Used in SeLeNe project. Indicates
additional textual description of the learning objective;for example, to

```

```

specify areas within the topic at a greater level of detail than is catered
for by the subject taxonomy (or ontology).</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#learning_objective_topic</IRI>
  <Literal datatypeIRI="xsd:string">Used in SeLeNe project. Indicates
the topic that the learning objective is about, referenced as an entry in
the RDF binding of a subject taxonomy or ontology (e.g. ACM Computing
Taxonomy)</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#learning_objective_verb</IRI>
  <Literal datatypeIRI="xsd:string">Used in SeLeNe project. A subset
of the outcome-illustrating verbs which characterise each type of learning
objectives specified by a committee of college and university examiners in
1956 (known as "Bloom's Taxonomy"). This subset has been selected
for the description of Learning Objectives by the SeLeNe project.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#learningstyle_taxonomy</IRI>
  <Literal datatypeIRI="xsd:string">A learning or cognitive style
taxonomy.

```

Enumerated

(Gardner, Gregorc, Honey and Mumford, Witkin's GEFT, Kolb LSI, Myers-Briggs, Dunn and Dunn, Sternberg)

```

</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#learningstyle_value</IRI>
  <Literal datatypeIRI="xsd:string">The value indicating the Learning
Style. This value is taken by the taxonomy defined in the
learningstyle_taxonomy property.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#lom_interactivitylevel</IRI>
  <Literal datatypeIRI="xsd:string">The degree of interactivity
characterizing this learning object. Interactivity in this context refers to
the degree to which the learner can influence the aspect or behavior of the
learning object, e.g. the degree to which the learning resource is able to
respond to the actions and input of the user.</Literal>
</AnnotationAssertion>
<AnnotationAssertion>
  <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
  <IRI>#lom_interactivitytype</IRI>
  <Literal datatypeIRI="xsd:string">The predominant mode of learning
interactivity supported by this learning object.

```

Values (Valid tokens in LOM. Restricted Vocabulary in SCORM):

- active
- expositive
- mixed

Definitions:

```

- Active: Indicates that the resource requires action on the part of the
user (e.g. the resource presents imperative statements, requires input).
- Expositive: Indicates that the resource provides information.
- Mixed: Indicates that the resource presents a mix of these two approaches.
</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#lom_learningResourceType</IRI>
    <Literal datatypeIRI="xsd:string"></Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#related_with</IRI>
    <Literal datatypeIRI="xsd:string">Relation of Learning Objects with
some Domain Concepts from a Domain ontology. The Domain ontology from which
the domain concepts are selected, is the ontology that has been used for the
indexing of the audiovisual material. </Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#semantics</IRI>
    <Literal datatypeIRI="xsd:string">The domain concept URL, on which
the value given corresponds. For example Carbon can exist both in a
Chemistry ontology and in a Biology Ontology. In this case there is no
significant problem. However, if we had a &quot;Ronaldo&quot; value, this
could be correspond to a soccer player and also to an Actor. Giving,
http://.../socceragents#Player we can say that in our case Ronaldo is a
Player. So, this property allows disambiguation.</Literal>
  </AnnotationAssertion>
  <AnnotationAssertion>
    <AnnotationProperty abbreviatedIRI="rdfs:comment"/>
    <IRI>#structure_type</IRI>
    <Literal datatypeIRI="xsd:string">Property taken from IMS Learning
Design specification. From the point of view of modeling a learning design,
an important feature to note is that ActivityStructures have an attribute
called structuretype, which can have one of two values, sequence or
selection. The default, if it is not included, is set to selection. This
means that when it is presented to the user, all the lower level activities
must be presented as some kind of menu or navigation aid for the user to
select which activity to carry out, when and in what order. If the
structuretype is set to sequence, then it means that the lower level
elements must be presented to the user in sequence. It is quite possible for
a sequence activity structure to contain a selection activity structure and
visa versa.</Literal>
  </AnnotationAssertion>
</Ontology>

```

A2.2 Instructional Model in XML Schema

```

<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified">
  <xs:include schemaLocation="learningDesignDataTypes.xsd"/>
  <xs:element name="learningDesign">
    <xs:complexType>
      <xs:sequence>

```

```

    <xs:element ref="metaData" minOccurs="1" maxOccurs="1"/>
    <xs:element ref="training" minOccurs="1" maxOccurs="1"/>
    <xs:element ref="learningObjectives" minOccurs="1" maxOccurs="1"/>
    <xs:element ref="lots" maxOccurs="1" minOccurs="1"/>

  </xs:sequence>
  <xs:attribute name="id" use="required" type="xs:ID"/>
</xs:complexType>
</xs:element>
<xs:element name="metaData">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="planner" minOccurs="1" maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="planner">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="firstname"/>
      <xs:element ref="lastname"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="firstname" type="xs:string"/>
<xs:element name="lastname" type="xs:string"/>
<xs:element name="training">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="title" minOccurs="1" maxOccurs="1"/>
      <xs:element ref="description" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element ref="trainingMethod" minOccurs="1" maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
    <xs:attribute name="lobjectiveref" use="required" type="xs:IDREF"/>
  </xs:complexType>
</xs:element>
<xs:element name="description" type="xs:string"/>
<xs:element name="trainingMethod">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="learningStyle"/>
      <xs:element ref="educationalLevel"/>
      <xs:element ref="difficulty"/>
      <xs:element ref="activityStructure" minOccurs="1"
maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
  </xs:complexType>
</xs:element>
<xs:element name="learningStyle">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="source"/>
      <xs:element ref="value"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="educationalLevel">

```

```

<xs:complexType>
  <xs:sequence>
    <xs:element ref="source"/>
    <xs:element ref="value"/>
  </xs:sequence>
</xs:complexType>
</xs:element>
<xs:element name="difficulty" type="difficultyValues"/>
<xs:element name="learningObjectives">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="learningObjective"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="learningObjective">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="verb"/>
      <xs:element ref="topic"/>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
  </xs:complexType>
</xs:element>
<xs:element name="verb" type="verbValues"/>
<xs:element name="topic">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="source"/>
      <xs:element ref="value"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="lots">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="lot" minOccurs="0"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="lot">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="learningResourceType" minOccurs="1"
maxOccurs="unbounded"/>
      <xs:element ref="format" minOccurs="0" maxOccurs="unbounded"/>
      <xs:element ref="interactivityType"/>
      <xs:element ref="interactivityLevel"/>
      <xs:element ref="domainConcept" minOccurs="0" maxOccurs="unbounded"/>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
  </xs:complexType>
</xs:element>
<xs:element name="learningResourceType" type="learningResourceTypeValues">
</xs:element>
<xs:element name="format" type="xs:string">
</xs:element>
<xs:element name="interactivityType" type="interactivityTypeValues">

```



```

</xs:element>
<xs:element name="interactivityLevel" type="interactivityLevelValues">
</xs:element>
<xs:element name="domainConcept" >
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="semantics" minOccurs="1" maxOccurs="1"/>
      <xs:element minOccurs="0" ref="value"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="semantics" type="xs:anyURI"/>
<xs:element name="title" type="xs:string"/>
<xs:element name="source" type="xs:anyURI"/>
<xs:element name="value" type="xs:string"/>

<xs:element name="activityStructure">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="title"/>
      <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:element ref="activityStructure" minOccurs="0"
maxOccurs="unbounded"/>
        <xs:element ref="activity" minOccurs="0" maxOccurs="unbounded"/>
      </xs:choice>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
    <xs:attribute name="lobjectiveref" use="required" type="xs:IDREF"/>
    <xs:attribute name="op" use="required" type="opValues"/>
  </xs:complexType>
</xs:element>

<xs:element name="activity">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="title"/>
    </xs:sequence>
    <xs:attribute name="id" use="required" type="xs:ID"/>
    <xs:attribute name="lobjectiveref" use="required" type="xs:IDREF"/>
    <xs:attribute name="lotref" use="required" type="xs:string"/>
  </xs:complexType>
</xs:element>

</xs:schema>

```

Appendix 3: Learner Model defining the input parameters to the personalization process

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified">
  <xs:element name="personalizationParameters">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="pedagogicalPreferences" maxOccurs="1"/>
        <xs:element ref="contentPreferences" maxOccurs="1"/>
        <xs:element ref="previousKnowledge" maxOccurs="1"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="pedagogicalPreferences">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="educ_diff" maxOccurs="1"/>
        <xs:element ref="learningStyle" maxOccurs="1"/>
        <xs:element ref="learningObjectives" maxOccurs="1"/>
        <xs:element ref="planner" maxOccurs="1"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="educ_diff">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="level" maxOccurs="1" minOccurs="1"/>
        <xs:element ref="difficulty" maxOccurs="1" minOccurs="1"/>
      </xs:sequence>
      <xs:attribute name="priority" use="optional" type="xs:decimal"/>
    </xs:complexType>
  </xs:element>
  <xs:element name="level" type="educationalLevelOptions"/>
  <xs:element name="difficulty" type="difficultyOptions"/>
  <xs:element name="learningStyle" type="learningStyleOptions"/>
  <xs:element name="learningObjectives">
    <xs:complexType>
      <xs:sequence>
        <xs:element maxOccurs="unbounded" ref="learningObjective"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
  <xs:element name="learningObjective">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="verb" maxOccurs="1" minOccurs="1"/>
        <xs:element ref="topic" maxOccurs="1" minOccurs="1"/>
      </xs:sequence>
      <xs:attribute name="priority" use="required" type="xs:decimal"/>
      <xs:attribute name="status" use="required" type="xs:decimal"/>
    </xs:complexType>
  </xs:element>
  <xs:element name="verb" type="xs:string"/>
  <xs:element name="topic" type="xs:string"/>

```

```

<xs:element name="planner" type="xs:string"/>
<xs:element name="contentPreferences">
  <xs:complexType>
    <xs:sequence>
      <xs:element ref="language" maxOccurs="1"/>
      <xs:element ref="devices" maxOccurs="1"/>
      <xs:element ref="learningProviders" maxOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="language" type="xs:string"/>

<xs:element name="devices">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="device" minOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="device" type="deviceOptions"/>

<xs:element name="learningProviders">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="learningProvider"
minOccurs="1"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
<xs:element name="learningProvider">
  <xs:complexType/>
</xs:element>

<xs:simpleType name="difficultyOptions">
  <xs:restriction base="xs:string">
    <xs:enumeration value="very easy"/>
    <xs:enumeration value="easy"/>
    <xs:enumeration value="medium"/>
    <xs:enumeration value="difficult"/>
    <xs:enumeration value="very difficult"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="learningStyleOptions">
  <xs:restriction base="xs:string">
    <xs:enumeration value="ExampleOriented"/>
    <xs:enumeration value="GeneralToSpecific"/>
    <xs:enumeration value="PracticeOriented"/>
    <xs:enumeration value="PrincipleOriented"/>
    <xs:enumeration value="SpecificToGeneral"/>
  </xs:restriction>
</xs:simpleType>

<xs:simpleType name="educationalLevelOptions">
  <xs:restriction base="xs:string">
    <xs:enumeration value="Primary"/>
    <xs:enumeration value="Secondary"/>
    <xs:enumeration value="Middle"/>
    <xs:enumeration value="Further"/>
  </xs:restriction>
</xs:simpleType>

```

```
<xs:enumeration value="Higher Education"/>
</xs:restriction>
</xs:simpleType>

<xs:simpleType name="deviceOptions">
  <xs:restriction base="xs:string">
    <xs:enumeration value="device 1"/>
    <xs:enumeration value="device 2"/>
    <xs:enumeration value="device 3"/>
    <xs:enumeration value="device 4"/>
    <xs:enumeration value="device 5"/>
  </xs:restriction>
</xs:simpleType>
<xs:element name="previousKnowledge">
  <xs:complexType>
    <xs:sequence>
      <xs:element maxOccurs="unbounded" ref="learningObjective"/>
    </xs:sequence>
  </xs:complexType>
</xs:element>
</xs:schema>
```

Appendix 4: A Learning Design teaching SCORM

```

<?xml version="1.0"?>
<learningDesign id="scorm2004_ld"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="learningDesign1.xsd">
  <metaData>
    <planner>
      <firstname>Polyxeni</firstname>
      <lastname>Arapi</lastname>
    </planner>
  </metaData>
  <training id="T120108115645" lobjectiveref="LV120108115645">
    <title>Sharable Content Object Reference Model (SCORM)</title>
    <description>A Training about Sharable Content Object Reference
Model</description>
    <trainingMethod id="TM120108132630">
      <learningStyle>
        <source>http://somehost/learningstyles.owl</source>
        <value>GeneralToSpecific</value>
      </learningStyle>
      <educationalLevel>
        <source>http://somehost/educationallevels.owl</source>
        <value>Further</value>
      </educationalLevel>
      <difficulty>very difficult</difficulty>
      <activityStructure id="AS120108132823" lobjectiveref="LV120108132823"
op="AND">
        <title>SCORM Overview</title>
        <activity id="A120108132824" lobjectiveref="LV120108132824"
lotref="LOT120108132824">
          <title>eLearning Standards Introduction</title>
          </activity>
          <activity id="A120108132825" lobjectiveref="LV120108132825"
lotref="LOT120108132825">
            <title>Advanced Distributed Learning (ADL)</title>
            </activity>
            <activity id="A120108132826" lobjectiveref="LV120108132826"
lotref="LOT120108132826">
              <title>What is SCORM?</title>
              </activity>
            </activityStructure>
          <activityStructure id="AS120108132827" lobjectiveref="LV120108132827"
op="AND">
            <title>Content Aggregation Model (CAM)</title>
            <activity id="A120108132828" lobjectiveref="LV120108132828"
lotref="LOT120108132828">
              <title>What is Content Aggregation Model?</title>
              </activity>
              <activity id="A120108132829" lobjectiveref="LV120108132829"
lotref="LOT120108132829">
                <title>Content Model</title>
                </activity>
                <activityStructure id="AS120108132830" lobjectiveref="LV120108132830"
op="AND">
                  <title>Content Model Components</title>
                  <activity id="A120108132831" lobjectiveref="LV120108132831"

```

```

lotref="LOT120108132831">
  <title>Assets</title>
</activity>
<activity id="A120108132832" lobjectiveref="LV120108132832"
lotref="LOT120108132832">
  <title>Sharable Content Objects (SCOs)</title>
</activity>
<activity id="A120108132833" lobjectiveref="LV120108132833"
lotref="LOT120108132833">
  <title>Content Organizations</title>
</activity>
<activityStructure id="AS120108132834"
lobjectiveref="LV120108132834" op="AND">
  <title>SCORM Metadata Components</title>
  <activity id="A120108132835" lobjectiveref="LV120108132835"
lotref="LOT120108132835">
    <title>SCORM Metadata Components Introduction</title>
  </activity>
  <activity id="A120108132836" lobjectiveref="LV120108132836"
lotref="LOT120108132836">
    <title>Content Aggregation Metadata</title>
  </activity>
  <activity id="A120108132837" lobjectiveref="LV120108132837"
lotref="LOT120108132837">
    <title>Content Organization Metadata</title>
  </activity>
  <activity id="A120108132838" lobjectiveref="LV120108132838"
lotref="LOT120108132838">
    <title>Activity Metadata</title>
  </activity>
  <activity id="A120108132839" lobjectiveref="LV120108132839"
lotref="LOT120108132839">
    <title>Sharable Content Object Metadata</title>
  </activity>
  <activity id="A120108132840" lobjectiveref="LV120108132840"
lotref="LOT120108132840">
    <title>Asset Metadata</title>
  </activity>
  <activity id="A120108132841" lobjectiveref="LV120108132841"
lotref="LOT120108132841">
    <title>Application of SCORM Metadata</title>
  </activity>
</activityStructure>
</activityStructure>
<activityStructure id="AS120108132842" lobjectiveref="LV120108132842"
op="AND">
  <title>Content Packaging</title>
  <activity id="A120108132843" lobjectiveref="LV120108132843"
lotref="LOT120108132843">
    <title>Content Packaging Introduction</title>
  </activity>
  <activityStructure id="AS120108132844"
lobjectiveref="LV120108132844" op="AND">
    <title>Content Package Components</title>
    <activity id="A120108132845" lobjectiveref="LV120108132845"
lotref="LOT120108132845">
      <title>Package</title>
    </activity>
  <activityStructure id="AS120108132846"

```

```

lobjectiveref="LV120108132846" op="AND">
  <title>Manifest</title>
  <activity id="A120108132847" lobjectiveref="LV120108132847"
lotref="LOT120108132847">
  <title>Manifest Introduction</title>
  </activity>
  <activityStructure id="AS120108132848"
lobjectiveref="LV120108132848" op="AND">
  <title>Manifest Components</title>
  <activity id="A120108132849" lobjectiveref="LV120108132849"
lotref="LOT120108132849">
  <title>Metadata</title>
  </activity>
  <activity id="A120108132850" lobjectiveref="LV120108132850"
lotref="LOT120108132850">
  <title>Organizations</title>
  </activity>
  <activity id="A120108132851" lobjectiveref="LV120108132851"
lotref="LOT120108132851">
  <title>Resources</title>
  </activity>
  <activity id="A120108132852" lobjectiveref="LV120108132852"
lotref="LOT120108132852">
  <title>(Sub) Manifests</title>
  </activity>
  </activityStructure>
</activityStructure>
  <activity id="A120108132853" lobjectiveref="LV120108132853"
lotref="LOT120108132853">
  <title>Physical Files</title>
  </activity>
  <activity id="A120108132854" lobjectiveref="LV120108132854"
lotref="LOT120108132854">
  <title>Package Interchange File (PIF)</title>
  </activity>
  </activityStructure>
</activityStructure>
  <activityStructure id="AS120108132855" lobjectiveref="LV120108132855"
op="AND">
  <title>Building Content Packages</title>
  <activity id="A120108132856" lobjectiveref="LV120108132856"
lotref="LOT120108132856">
  <title>Manifest File</title>
  </activity>
  <activity id="A120108132857" lobjectiveref="LV120108132857"
lotref="LOT120108132857">
  <title>(Sub) Manifests</title>
  </activity>
  </activityStructure>
</activityStructure>
</trainingMethod>
</training>

<learningObjectives>
<learningObjective id="LV120108115645">
  <verb>comprehend</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>

```

```

    <value>Sharable Content Object Reference Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132823">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Sharable Content Object Reference Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132824">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>eLearning Standard</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132825">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Advanced Distributed Learning (ADL)</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132826">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Sharable Content Object Reference Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132827">
  <verb>comprehend</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Aggregation Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132828">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Aggregation Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132829">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Model</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132830">
  <verb>distinguish</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Model Components</value>
  </topic>
</learningObjective>

```



```
<learningObjective id="LV120108132831">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Asset</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132832">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Sharable Content Object</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132833">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Organization</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132834">
  <verb>distinguish</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>SCORM Metadata Components</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132835">
  <verb>list</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>SCORM Metadata Components</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132836">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Aggregation Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132837">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Organization Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132838">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Activity Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132839">
  <verb>define</verb>
  <topic>
```

```

    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Sharable Content Object Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132840">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Asset Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132841">
  <verb>apply</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>SCORM Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132842">
  <verb>comprehend</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Packaging</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132843">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Packaging</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132844">
  <verb>distinguish</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Package Components</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132845">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Package</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132846">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132847">
  <verb>define</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest</value>
  </topic>

```

```

</learningObjective>
<learningObjective id="LV120108132848">
  <verb>distinguish</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest Components</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132849">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest Metadata</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132850">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest Organizations</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132851">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Manifest Resources</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132852">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>SubManifest</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132853">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Physical Files</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132854">
  <verb>describe</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Package Interchange File</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132855">
  <verb>construct</verb>
  <topic>
    <source>http://somehost/scorm2004ontology.owl</source>
    <value>Content Package</value>
  </topic>
</learningObjective>
<learningObjective id="LV120108132856">
  <verb>construct</verb>

```

```

    <topic>
      <source>http://somehost/scorm2004ontology.owl</source>
      <value>Manifest File</value>
    </topic>
  </learningObjective>
  <learningObjective id="LV120108132857">
    <verb>combine</verb>
    <topic>
      <source>http://somehost/scorm2004ontology.owl</source>
      <value>SubManifest</value>
    </topic>
  </learningObjective>
</learningObjectives>

<lots>
  <!-- lot for Activity "What is SCORM"? -->
  <lot id="LOT120108132823">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>low</interactivityLevel>
  </lot>
  <!-- lot for Activity "eLearning Standards Introduction" -->
  <lot id="LOT120108132824">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Advanced Distributed Learning (ADL)" -->
  <lot id="LOT120108132825">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "What is Content Aggregation Model?" -->
  <lot id="LOT120108132828">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Content Model" -->
  <lot id="LOT120108132829">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Assets" -->
  <lot id="LOT120108132831">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Sharable Content Objects (SCOs)" -->
  <lot id="LOT120108132832">

```

```

    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Content Organizations" -->
  <lot id="LOT120108132833">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "SCORM Metadata Components Introduction" -->
  <lot id="LOT120108132835">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Content Aggregation Metadata" -->
  <lot id="LOT120108132836">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Content Organization Metadata" -->
  <lot id="LOT120108132837">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Activity Metadata" -->
  <lot id="LOT120108132838">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Sharable Content Object Metadata" -->
  <lot id="LOT120108132839">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Asset Metadata" -->
  <lot id="LOT120108132840">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
  </lot>
  <!-- lot for Activity "Application of SCORM Metadata" -->
  <lot id="LOT120108132841">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>

```

```

    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Content Packaging Introduction" -->
<lot id="LOT120108132843">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Package" -->
<lot id="LOT120108132845">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Manifest Introduction" -->
<lot id="LOT120108132847">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Metadata" -->
<lot id="LOT120108132849">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Organizations" -->
<lot id="LOT120108132850">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Resources" -->
<lot id="LOT120108132851">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "(Sub)Manifests" -->
<lot id="LOT120108132852">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Physical Files" -->
<lot id="LOT120108132853">
    <learningResourceType>lecture</learningResourceType>
    <format>text/html</format>
    <interactivityType>active</interactivityType>
    <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Package Interchange File (PIF)" -->

```

```
<lot id="LOT120108132854">
  <learningResourceType>lecture</learningResourceType>
  <format>text/html</format>
  <interactivityType>active</interactivityType>
  <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "Manifest File" -->
<lot id="LOT120108132856">
  <learningResourceType>lecture</learningResourceType>
  <format>text/html</format>
  <interactivityType>active</interactivityType>
  <interactivityLevel>very low</interactivityLevel>
</lot>
<!-- lot for Activity "(Sub)Manifests" -->
<lot id="LOT120108132857">
  <learningResourceType>lecture</learningResourceType>
  <format>text/html</format>
  <interactivityType>active</interactivityType>
  <interactivityLevel>very low</interactivityLevel>
</lot>
</lots>
</learningDesign>
```

Appendix 5: XML schemata for filters used in LOGOS Repositories

A5.1 MPEG7 filter schema

```
<?xml version="1.0" encoding="utf-8"?>
<!--xmlns="http://www.ina.org" targetNamespace="http://www.ina.org" -->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
  <xsd:element name="Query">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="MediaFilter" type="FilterDef" minOccurs="0"/>
        <xsd:element name="DigitalObjectFilter" type="FilterDef"
minOccurs="0"/>
        <!--implicit AND between the two subtrees -->
      </xsd:sequence>
    </xsd:complexType>
  </xsd:element>
  <xsd:complexType name="FilterDef">
    <xsd:sequence>
      <xsd:element name="Uterm" type="utermDef" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
  </xsd:complexType>
  <xsd:complexType name="utermDef">
    <xsd:sequence>
      <xsd:element name="Lterm" type="LtermDef" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
  </xsd:complexType>
  <xsd:complexType name="LtermDef">
    <xsd:sequence>
      <xsd:element name="Atom" type="AtomType" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
  </xsd:complexType>
  <xsd:complexType name="AtomType">
    <xsd:choice>
      <xsd:element name="DO_Id"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="DO_Status" type="RelationalExpression_StatusType"/>
      <xsd:element name="DO_Type" type="RelationalExpression_DOType"/>
      <xsd:element name="DO_SupportId"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="DO_Title" type="RelationalExpression_String"/>
      <xsd:element name="DO_Abstract" type="RelationalExpression_String"/>
      <xsd:element name="DO_Author_Id"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="DO_Author_GivenName"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="DO_Author_FamilyName"
type="RelationalExpression_StringWithoutLanguage"/>
    </xsd:choice>
  </xsd:complexType>
</xsd:schema>
```



```

    <xsd:element name="DO_Author_OrganizationId"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="DO_Author_OrganizationName"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="DO_Duration"
type="RelationalExpression_MediaDuration"/>
    <xsd:element name="DO_Height" type="RelationalExpression_Number"/>
    <xsd:element name="DO_Width" type="RelationalExpression_Number"/>
    <xsd:element name="DO_EventDate" type="RelationalExpression_DateTime"/>
    <xsd:element name="DO_EventDuration"
type="RelationalExpression_Duration"/>
    <xsd:element name="Media_Id"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="Media_Type"
type="RelationalExpression_AvailabilityPeriodType"/>
    <xsd:element name="Media_Title" type="RelationalExpression_String"/>
    <xsd:element name="Media_Abstract" type="RelationalExpression_String"/>
    <xsd:element name="Media_OriginalLanguage"
type="RelationalExpression_CountryType"/>
    <xsd:element name="Media_DubbedLanguage"
type="RelationalExpression_CountryType"/>
    <xsd:element name="Media_SubtitledLanguage"
type="RelationalExpression_CountryType"/>
    <xsd:element name="Media_Availability_Region"
type="RelationalExpression_RegionType"/>
    <xsd:element name="Media_Availability_DisseminationFormat"
type="RelationalExpression_DisseminationFormatType"/>
    <xsd:element name="Media_Availability_RightsOwner"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="Media_Availability_Type"/>
    <xsd:element name="Media_Availability_StartDate"
type="RelationalExpression_DateTime"/>
    <xsd:element name="Media_Availability_Duration"
type="RelationalExpression_Duration"/>
    <xsd:element name="Media_CreationDate"
type="RelationalExpression_DateTime"/>
    <xsd:element name="Media_ArchivingDate"
type="RelationalExpression_DateTime"/>
  </xsd:choice>
  <xsd:attribute name="flag" type="NOT" use="optional"/>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Number">
  <xsd:simpleContent>
    <xsd:extension base="xsd:integer">
      <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_String">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
      <xsd:attribute name="language" type="countryCode" use="optional"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_StringWithoutLanguage">

```

```

    <xsd:simpleContent>
      <xsd:extension base="xsd:string">
        <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_DateTime">
    <xsd:simpleContent>
      <xsd:extension base="xsd:dateTime">
        <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_Duration">
    <xsd:simpleContent>
      <xsd:extension base="xsd:duration">
        <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_MediaDuration">
    <xsd:complexContent>
      <xsd:extension base="basicDurationType">
        <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_DOType">
    <xsd:simpleContent>
      <xsd:extension base="DOType">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_CountryType">
    <xsd:complexContent>
      <xsd:extension base="countryCode">
        <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:complexContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_DisseminationFormatType">
    <xsd:simpleContent>
      <xsd:extension base="DisseminationFormatType">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_AvailabilityPeriodType">
    <xsd:simpleContent>
      <xsd:extension base="AvailabilityPeriodType">
        <xsd:attribute name="op" type="EnumRelationalOperator"

```

```

use="required"/>
  </xsd:extension>
</xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_RegionType">
  <xsd:complexContent>
    <xsd:extension base="regionCode">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_StatusType">
  <xsd:simpleContent>
    <xsd:extension base="Status">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="DOType">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="AudioVisualSegment"/>
    <xsd:enumeration value="StillRegion"/>
    <xsd:enumeration value="AudioSegment"/>
    <xsd:enumeration value="VideoSegment"/>
    <xsd:enumeration value="Image"/>
    <xsd:enumeration value="AudioVisual"/>
    <xsd:enumeration value="Audio"/>
    <xsd:enumeration value="Video"/>
    <xsd:enumeration value="Doc"/>
    <xsd:enumeration value="Flash"/>
    <xsd:enumeration value="Pdf"/>
    <xsd:enumeration value="Html"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="DisseminationFormatType">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="Terrestrial"/>
    <xsd:enumeration value="Cable"/>
    <xsd:enumeration value="Satellite"/>
    <xsd:enumeration value="Internet"/>
    <xsd:enumeration value="Print"/>
    <xsd:enumeration value="CD"/>
    <xsd:enumeration value="LaserDisc"/>
    <xsd:enumeration value="DVD"/>
    <xsd:enumeration value="Magnetic Disk"/>
    <xsd:enumeration value="Magnetic Tape"/>
    <xsd:enumeration value="Magneto-Optical Media"/>
    <xsd:enumeration value="Solid State Memory"/>
    <xsd:enumeration value="Vinyl Record"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="AvailabilityPeriodType">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="live"/>
    <xsd:enumeration value="repeat"/>
    <xsd:enumeration value="firstshowing"/>
    <xsd:enumeration value="lastshowing"/>
  </xsd:restriction>

```

```

    <xsd:enumeration value="conditionalAccess"/>
    <xsd:enumeration value="encrypted"/>
    <xsd:enumeration value="payPerUse"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="Status">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="private"/>
    <xsd:enumeration value="editable"/>
    <xsd:enumeration value="rendered"/>
  </xsd:restriction>
  <!-- used by the CDT tool, all other tools will implicitly reach rendered
DO only -->
</xsd:simpleType>
<xsd:simpleType name="LogicOperand">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="or"/>
    <xsd:enumeration value="and"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="NOT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="not"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="NumberRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value=">"/>
    <xsd:enumeration value="<"/>
    <xsd:enumeration value="!=">
    <xsd:enumeration value="=">
    <xsd:enumeration value=">=">
    <xsd:enumeration value="<=">
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="StringRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value=">"/>
    <xsd:enumeration value="<"/>
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
    <xsd:enumeration value=">=">
    <xsd:enumeration value="<=">
    <xsd:enumeration value="contains"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="EnumRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
  </xsd:restriction>
</xsd:simpleType>
<!-- ##### -->
<!-- MPEG7 Definition of countryCode datatype (5_5.6.3) -->
<!-- ##### -->
<!-- Definition of countryCode datatype -->
<xsd:simpleType name="countryCode">
  <xsd:restriction base="xsd:string">
    <xsd:whiteSpace value="collapse"/>

```

```

    <xsd:pattern value="[a-zA-Z]{2}"/>
  </xsd:restriction>
</xsd:simpleType>
<!-- ##### -->
<!-- MPEG7 Definition of regionCode datatype (5_5.6.4) -->
<!-- ##### -->
<!-- Definition of regionCode datatype -->
<xsd:simpleType name="regionCode">
  <xsd:restriction base="xsd:string">
    <xsd:whiteSpace value="collapse"/>
    <xsd:pattern value="[a-zA-Z]{2}(-[a-zA-Z0-9]{1,3})?"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="basicDurationType">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="PT\d{2}H\d{2}M\d{2}S\d{1,8}N14112000F"/>
  </xsd:restriction>
</xsd:simpleType>
</xsd:schema>

```

A5.2 Semantic filter schema

Semantic filters are represented using the COGXML format as simple graphs. The DTD of the COGXML format is given next:

```

<?xml version="1.0" encoding="UTF-8"?>
<!--

DTD CoGXML 1.2

Cette DTD permet la représentation d'un support, de graphes conceptuels
et de règles de graphes.

Pour se référer à cette DTD, utiliser la syntaxe suivante :
<!DOCTYPE CoGXML PUBLIC "-//COGITANT//CoGXML Format Specification 1.2//EN"
"http://cogitant.sourceforge.net/cogxml.dtd">

Ce fichier fait partie de CoGITANT, une bibliothèque pour la construction
d'applications sur les graphes conceptuels, disponible sous licence GPL.
http://cogitant.sourceforge.net
CoGITANT version 5.1.8 - dernière modification de la DTD : 14/09/2006

-->
<!-- Extensions des attributs des balises standard. -->
<!ENTITY % cogxmlExtensions "">
<!ENTITY % supportExtensions "">
<!ENTITY % conceptTypesExtensions "">
<!ENTITY % relationTypesExtensions "">
<!ENTITY % nestingTypesExtensions "">
<!ENTITY % conformityExtensions "">
<!ENTITY % bannedTypesExtensions "">
<!ENTITY % supportObjectExtensions "">
<!ENTITY % ctypeExtensions "">
<!ENTITY % rtypeExtensions "">
<!ENTITY % ntypeExtensions "">
<!ENTITY % markerExtensions "">
<!ENTITY % orderExtensions "">
<!ENTITY % bannedTypeExtensions "">

```

```

<!ENTITY % graphExtensions "">
<!ENTITY % environmentObjectExtensions "">
<!ENTITY % nodeExtensions "">
<!ENTITY % conceptExtensions "">
<!ENTITY % nestingExtensions "">
<!ENTITY % relationExtensions "">
<!ENTITY % edgeExtensions "">
<!ENTITY % ruleExtensions "">
<!ENTITY % conPtsExtensions "">
<!ENTITY % coupleExtensions "">
<!ENTITY % subPropExtensions "">
<!-- Document. -->
<!ELEMENT cogxml (support?, (graph | rule)*)>
<!ATTLIST cogxml
    app CDATA #IMPLIED
    %cogxmlExtensions;
>
<!-- Propriétés supplémentaires des chaque objet du modèle. -->
<!ELEMENT subprop EMPTY>
<!ATTLIST subprop
    subid CDATA #REQUIRED
    %subPropExtensions;
>
<!-- Support. -->
<!ELEMENT support (conceptTypes, relationTypes?, nestingTypes?, conformity?,
bannedTypes?, subprop*)>
<!ATTLIST support
    name CDATA #IMPLIED
    %supportExtensions;
>
<!ELEMENT conceptTypes (ctype*, order*)>
<!ATTLIST conceptTypes
    %conceptTypesExtensions;
>
<!ELEMENT ctype (subprop*)>
<!ATTLIST ctype
    id ID #IMPLIED
    label CDATA #REQUIRED
    %supportObjectExtensions;
    %ctypeExtensions;
>
<!ELEMENT order EMPTY>
<!ATTLIST order
    id1 IDREF #IMPLIED
    id2 IDREF #IMPLIED
    label1 CDATA #IMPLIED
    label2 CDATA #IMPLIED
>
<!ELEMENT relationTypes (rtype*, order*)>
<!ATTLIST relationTypes
    %relationTypesExtensions;
>
<!ELEMENT rtype (subprop*)>
<!ATTLIST rtype
    id ID #IMPLIED
    label CDATA #REQUIRED
    idSignature CDATA #IMPLIED
    labelSignature CDATA #IMPLIED
    %supportObjectExtensions;

```

```

    %rtypeExtensions;
  >
  <!-- ELEMENT nestingTypes (ntype*, order*) -->
  <!-- ATTLIST nestingTypes
    %nestingTypesExtensions;
  -->
  <!-- ELEMENT ntype (subprop*) -->
  <!-- ATTLIST ntype
    id ID #IMPLIED
    label CDATA #REQUIRED
    %supportObjectExtensions;
    %ntypeExtensions;
  -->
  <!-- ELEMENT conformity (marker*) -->
  <!-- ATTLIST conformity
    %conformityExtensions;
  -->
  <!-- ELEMENT marker (subprop*) -->
  <!-- ATTLIST marker
    id ID #IMPLIED
    label CDATA #REQUIRED
    idType IDREF #IMPLIED
    labelType CDATA #IMPLIED
    %supportObjectExtensions;
    %markerExtensions;
  -->
  <!-- ELEMENT bannedTypes (bannedType*) -->
  <!-- ATTLIST bannedTypes
    %bannedTypesExtensions;
  -->
  <!-- ELEMENT bannedType (type*) -->
  <!-- ATTLIST bannedType
    %bannedTypeExtensions;
  -->
  <!-- ELEMENT type -->
  <!-- ATTLIST type
    id CDATA #IMPLIED
    label CDATA #IMPLIED
  -->
  <!-- Graphe. -->
  <!-- ELEMENT graph (concept*, relation*, edge*, subprop*) -->
  <!-- ATTLIST graph
    id ID #REQUIRED
    nature CDATA #IMPLIED
    set CDATA #IMPLIED
    %environmentObjectExtensions;
    %nodeExtensions;
    %graphExtensions;
  -->
  <!-- ELEMENT concept (type*, nesting*, subprop*) -->
  <!-- Si le type du concept est un type conjonctif, les attributs idType et
    labelType ne sont pas donnés, mais des éléments type sont emboîtés dans
    concept. -->
  <!-- ATTLIST concept
    id ID #REQUIRED
    idType CDATA #IMPLIED
    labelType CDATA #IMPLIED
    coreferenceClass CDATA #IMPLIED
    referent (generic | individual | variable) "generic"
  -->

```

```

    idMarker CDATA #IMPLIED
    labelMarker CDATA #IMPLIED
    %nodeExtensions;
    %conceptExtensions;
  >
<!-- ELEMENT nesting (subprop*) -->
<!-- ATTLIST nesting
    idType CDATA #IMPLIED
    labelType CDATA #IMPLIED
    nestGraph CDATA #REQUIRED
    %nodeExtensions;
    %nestingExtensions;
  >
<!-- ELEMENT relation (subprop*) -->
<!-- ATTLIST relation
    id ID #REQUIRED
    idType CDATA #IMPLIED
    labelType CDATA #IMPLIED
    %nodeExtensions;
    %relationExtensions;
  >
<!-- ELEMENT edge EMPTY -->
<!-- ATTLIST edge
    rid IDREF #REQUIRED
    cid IDREF #REQUIRED
    label CDATA #REQUIRED
    %edgeExtensions;
  >
<!-- Règle. -->
<!-- ELEMENT rule (hypt, conc, conPts, subprop*) -->
<!-- ATTLIST rule
    id ID #REQUIRED
    %environmentObjectExtensions;
    %ruleExtensions;
  >
<!-- ELEMENT hypt (graph) -->
<!-- ELEMENT conc (graph) -->
<!-- ELEMENT conPts (couple*) -->
<!-- ATTLIST conPts
    %conPtsExtensions;
  >
<!-- ELEMENT couple EMPTY -->
<!-- ATTLIST couple
    idC1 IDREF #REQUIRED
    idC2 IDREF #REQUIRED
    %coupleExtensions;
  >

```

A5.3 Boolean LOM filter schema

```

<?xml version="1.0"?>
<!--xmlns="http://www.musicTuc.org"
targetNamespace="http://www.musicTuc.org" -->
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
elementFormDefault="qualified" attributeFormDefault="unqualified">
  <xsd:element name="Query">
    <xsd:complexType>

```



```

    <xsd:sequence>
      <xsd:element name="Uterm" type="utermDef" maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
  </xsd:complexType>
</xsd:element>
<xsd:complexType name="utermDef">
  <xsd:sequence>
    <xsd:element name="Lterm" type="LtermDef" maxOccurs="unbounded"/>
  </xsd:sequence>
  <xsd:attribute name="type" type="LogicOperand" use="required"/>
  <xsd:attribute name="flag" type="NOT" use="optional"/>
</xsd:complexType>
<xsd:complexType name="LtermDef">
  <xsd:sequence>
    <xsd:element name="Atom" type="AtomType" maxOccurs="unbounded"/>
  </xsd:sequence>
  <xsd:attribute name="type" type="LogicOperand" use="required"/>
  <xsd:attribute name="flag" type="NOT" use="optional"/>
</xsd:complexType>
<xsd:complexType name="AtomType">
  <xsd:choice>
    <xsd:element name="general_identifier"
type="RelationalExpression_identifier"/>
    <xsd:element name="general_title_string"
type="RelationalExpression_String"/>
    <xsd:element name="general_language" type="RelationalExpression_GL"/>
    <xsd:element name="general_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="general_keyword_string"
type="RelationalExpression_String"/>
    <xsd:element name="general_coverage_string"
type="RelationalExpression_String"/>
    <xsd:element name="general_structure"
type="RelationalExpression_GStructure"/>
    <xsd:element name="general_aggregationLevel_value"
type="RelationalExpression_AggregationlevelValue"/>
    <xsd:element name="lifeCycle_version_string"
type="RelationalExpression_String"/>
    <xsd:element name="lifeCycle_status_value"
type="RelationalExpression_Status"/>
    <xsd:element name="lifeCycle_contribute"
type="RelationalExpression_Contribution"/>
    <xsd:element name="metaMetadata_identifier"
type="RelationalExpression_identifier"/>
    <xsd:element name="metaMetadata_contribute"
type="RelationalExpression_Contribution"/>
    <xsd:element name="metaMetadata_schema"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="metaMetadata_language"
type="RelationalExpression_GL"/>
    <xsd:element name="technical_format"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="technical_size" type="RelationalExpression_TS"/>
    <xsd:element name="technical_location"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="technical_requirement_orComposite"
type="RelationalExpression_Trequirement"/>
  </xsd:choice>

```

```

    <xsd:element name="technical_InstallationRemarks"
type="RelationalExpression_String"/>
    <xsd:element name="technical_OtherPlatformRequirements"
type="RelationalExpression_String"/>
    <xsd:element name="technical_duration_duration"
type="RelationalExpression_Duration"/>
    <xsd:element name="technical_duration_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_interactivityType_value"
type="RelationalExpression_EIT"/>
    <xsd:element name="educational_learningResourceType_value"
type="RelationalExpression_ELV"/>
    <xsd:element name="educational_interactivityLevel_value"
type="RelationalExpression_EIV"/>
    <xsd:element name="educational_semanticDensity_value"
type="RelationalExpression_ESV"/>
    <xsd:element name="educational_intendedEndUserRole_value"
type="RelationalExpression_ENDUSERROLE"/>
    <xsd:element name="educational_context_value"
type="RelationalExpression_ECV"/>
    <xsd:element name="educational_typicalAgeRange_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_difficulty_value"
type="RelationalExpression_EDV"/>
    <xsd:element name="educational_typicalLearningTime_duration"
type="RelationalExpression_Duration"/>
    <xsd:element name="educational_typicalLearningTime_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_language"
type="RelationalExpression_GL"/>
    <xsd:element name="rights_cost_value"
type="RelationalExpression_CostV"/>
    <xsd:element name="rights_copyrightAndOtherRestrictions_value"
type="RelationalExpression_CostV"/>
    <xsd:element name="rights_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="relation_entry" type="RelationExpression_Relation"/>
    <xsd:element name="annotation_entry"
type="RelationalExpression_Anotation"/>
    <xsd:element name="classification_entry" type="classification_type"/>
  </xsd:choice>
  <xsd:attribute name="flag" type="NOT" use="optional"/>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_identifier">
  <xsd:all>
    <xsd:element name="catalog"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="entry"
type="RelationalExpression_StringWithoutLanguage"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_GStructure">
  <xsd:simpleContent>
    <xsd:extension base="GStructure">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>

```

```

</xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="GStructure">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="atomic"/>
    <xsd:enumeration value="collection"/>
    <xsd:enumeration value="networked"/>
    <xsd:enumeration value="hierarchical"/>
    <xsd:enumeration value="linear"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_AggregationlevelValue">
  <xsd:simpleContent>
    <xsd:extension base="AggregationlevelValue">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="AggregationlevelValue">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="1"/>
    <xsd:enumeration value="2"/>
    <xsd:enumeration value="3"/>
    <xsd:enumeration value="4"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_Version">
  <xsd:simpleContent>
    <xsd:extension base="Version">
      <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="Version">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="([0-9]+)|([0-9]+\.[0-9]+)"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_Status">
  <xsd:simpleContent>
    <xsd:extension base="Status">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="Status">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="draft"/>
    <xsd:enumeration value="final"/>
    <xsd:enumeration value="revised"/>
    <xsd:enumeration value="unavailable"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_Contribution">
  <xsd:all>
    <xsd:element name="role_value" type="RelationalExpression_CR"

```

```

minOccurs="0"/>
  <xsd:element name="entity"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
  <xsd:element name="date_dateTime" type="RelationalExpression_DateTime"
minOccurs="0"/>
  <xsd:element name="date_description_string"
type="RelationalExpression_String" minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationExpression_Resource">
<xsd:all>
  <xsd:element name="identifier" type="RelationalExpression_identifier"
minOccurs="0"/>
  <xsd:element name="description_string"
type="RelationalExpression_String" minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Anotation">
<xsd:all>
  <xsd:element name="annotation_entity"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
  <xsd:element name="annotation_date_dateTime"
type="RelationalExpression_DateTime" minOccurs="0"/>
  <xsd:element name="annotation_date_description_string"
type="RelationalExpression_String" minOccurs="0"/>
  <xsd:element name="annotation_description_string"
type="RelationalExpression_String" minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationExpression_Relation">
<xsd:all>
  <xsd:element name="kind_value" type="RelationalExpression_RKV"
minOccurs="0"/>
  <xsd:element name="relation_resource"
type="RelationExpression_Resource" minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="classification_type">
<xsd:all>
  <xsd:element name="purpose_value" type="RelationalExpression_CPV"
minOccurs="0"/>
  <xsd:element name="taxonPathEntry"
type="RelationalExpression_taxonPath" minOccurs="0"/>
  <xsd:element name="description_string"
type="RelationalExpression_String" minOccurs="0"/>
  <xsd:element name="keyword_string" type="RelationalExpression_String"
minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_taxonPath">
<xsd:all>
  <xsd:element name="source_string" type="RelationalExpression_String"
minOccurs="0"/>
  <xsd:element name="taxon_entry" type="RelationalExpression_taxon"
minOccurs="0"/>
</xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_taxon">
<xsd:all>

```

```

    <xsd:element name="id"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
    <xsd:element name="entry_string" type="RelationalExpression_String"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Trequirement">
  <xsd:all>
    <xsd:element name="type_value" type="RelationalExpression_TV"
minOccurs="0"/>
    <xsd:element name="name_value" type="RelationalExpression_NV"
minOccurs="0"/>
    <xsd:element name="maximumVersion" type="RelationalExpression_Version"
minOccurs="0"/>
    <xsd:element name="minimumVersion" type="RelationalExpression_Version"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_DateTime">
  <xsd:simpleContent>
    <xsd:extension base="xsd:dateTime">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Duration">
  <xsd:simpleContent>
    <xsd:extension base="xsd:duration">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_CostV">
  <xsd:simpleContent>
    <xsd:extension base="CostV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="CostV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="yes"/>
    <xsd:enumeration value="no"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_StringWithoutLanguage">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_TS">
  <xsd:simpleContent>
    <xsd:extension base="TS">

```

```

        <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
    </xsd:extension>
</xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="TS">
    <xsd:restriction base="xsd:string">
        <xsd:pattern value="[0-9] +"/>
    </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_CPV">
    <xsd:simpleContent>
        <xsd:extension base="CPV">
            <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
        </xsd:extension>
    </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="CPV">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="discipline"/>
        <xsd:enumeration value="idea"/>
        <xsd:enumeration value="prerequisite"/>
        <xsd:enumeration value="educational objective"/>
        <xsd:enumeration value="accessibility"/>
        <xsd:enumeration value="restrictions"/>
        <xsd:enumeration value="educational level"/>
        <xsd:enumeration value="skill level"/>
        <xsd:enumeration value="security level"/>
        <xsd:enumeration value="competency"/>
    </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_CTES">
    <xsd:simpleContent>
        <xsd:extension base="xsd:string">
            <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
        </xsd:extension>
    </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_MetaCRV">
    <xsd:simpleContent>
        <xsd:extension base="MetaCRV">
            <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
        </xsd:extension>
    </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="MetaCRV">
    <xsd:restriction base="xsd:string">
        <xsd:enumeration value="creator"/>
        <xsd:enumeration value="validator"/>
    </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_RKV">
    <xsd:simpleContent>
        <xsd:extension base="RKV">
            <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
        </xsd:extension>
    </xsd:simpleContent>
</xsd:complexType>

```

```

    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="RKV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="ispartof"/>
    <xsd:enumeration value="haspart"/>
    <xsd:enumeration value="isversionof"/>
    <xsd:enumeration value="hasversion"/>
    <xsd:enumeration value="isformatof"/>
    <xsd:enumeration value="hasformat"/>
    <xsd:enumeration value="references"/>
    <xsd:enumeration value="isreferencedby"/>
    <xsd:enumeration value="isbasedon"/>
    <xsd:enumeration value="isbasisfor"/>
    <xsd:enumeration value="requires"/>
    <xsd:enumeration value="isrequiredby"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EDV">
  <xsd:simpleContent>
    <xsd:extension base="EDV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EDV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very easy"/>
    <xsd:enumeration value="easy"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="difficult"/>
    <xsd:enumeration value="very difficult"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ECV">
  <xsd:simpleContent>
    <xsd:extension base="ECV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ECV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="school"/>
    <xsd:enumeration value="higher education"/>
    <xsd:enumeration value="training"/>
    <xsd:enumeration value="other"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ENDUSERROLE">
  <xsd:simpleContent>
    <xsd:extension base="ENDUSERROLE">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>

```

```

</xsd:complexType>
<xsd:simpleType name="ENDUSERROLE">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="teacher"/>
    <xsd:enumeration value="author"/>
    <xsd:enumeration value="learner"/>
    <xsd:enumeration value="manager"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ESV">
  <xsd:simpleContent>
    <xsd:extension base="ESV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ESV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very low"/>
    <xsd:enumeration value="low"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="high"/>
    <xsd:enumeration value="very high"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EIV">
  <xsd:simpleContent>
    <xsd:extension base="EIV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EIV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very low"/>
    <xsd:enumeration value="low"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="high"/>
    <xsd:enumeration value="very high"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ELV">
  <xsd:simpleContent>
    <xsd:extension base="ELV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ELV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="exercise"/>
    <xsd:enumeration value="simulation"/>
    <xsd:enumeration value="questionnaire"/>
    <xsd:enumeration value="diagram"/>
    <xsd:enumeration value="figure"/>
    <xsd:enumeration value="graph"/>
  </xsd:restriction>
</xsd:simpleType>

```



```

    <xsd:enumeration value="index"/>
    <xsd:enumeration value="slide"/>
    <xsd:enumeration value="table"/>
    <xsd:enumeration value="narrative text"/>
    <xsd:enumeration value="exam"/>
    <xsd:enumeration value="experiment"/>
    <xsd:enumeration value="problem statement"/>
    <xsd:enumeration value="self assessment"/>
    <xsd:enumeration value="lecture"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_GL">
  <xsd:simpleContent>
    <xsd:extension base="GL">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_String">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
      <xsd:attribute name="language" type="GL" use="optional"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="GL">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="([a-zA-Z]{1,8}) (-[a-zA-Z0-9]{1,8}) *"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_CR">
  <xsd:simpleContent>
    <xsd:extension base="CR">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="CR">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="author"/>
    <xsd:enumeration value="publisher"/>
    <xsd:enumeration value="unknown"/>
    <xsd:enumeration value="initiator"/>
    <xsd:enumeration value="terminator"/>
    <xsd:enumeration value="validator"/>
    <xsd:enumeration value="editor"/>
    <xsd:enumeration value="graphical designer"/>
    <xsd:enumeration value="technical implementer"/>
    <xsd:enumeration value="content provider"/>
    <xsd:enumeration value="technical validator"/>
    <xsd:enumeration value="educational validator"/>
    <xsd:enumeration value="script writer"/>
    <xsd:enumeration value="instructional designer"/>
    <xsd:enumeration value="subject matter expert"/>
  </xsd:restriction>

```

```

</xsd:simpleType>
<xsd:complexType name="RelationalExpression_TV">
  <xsd:simpleContent>
    <xsd:extension base="TV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="TV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="operating system"/>
    <xsd:enumeration value="browser"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_NV">
  <xsd:simpleContent>
    <xsd:extension base="NV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="NV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="pc-dos"/>
    <xsd:enumeration value="ms-windows"/>
    <xsd:enumeration value="macos"/>
    <xsd:enumeration value="unix"/>
    <xsd:enumeration value="multi-os"/>
    <xsd:enumeration value="none"/>
    <xsd:enumeration value="any"/>
    <xsd:enumeration value="netscape"/>
    <xsd:enumeration value="communicator"/>
    <xsd:enumeration value="ms-internet explorer"/>
    <xsd:enumeration value="opera"/>
    <xsd:enumeration value="amaya"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EIT">
  <xsd:simpleContent>
    <xsd:extension base="EIT">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EIT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="active"/>
    <xsd:enumeration value="expositive"/>
    <xsd:enumeration value="mixed"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="LogicOperand">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="or"/>
    <xsd:enumeration value="and"/>
  </xsd:restriction>

```

```

</xsd:simpleType>
<xsd:simpleType name="NOT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="not"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="NumberRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value=">"/>
    <xsd:enumeration value="<"/>
    <xsd:enumeration value="!=">
    <xsd:enumeration value="=">
    <xsd:enumeration value=">=">
    <xsd:enumeration value="<=">
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="StringRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value=">"/>
    <xsd:enumeration value="<"/>
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
    <xsd:enumeration value=">=">
    <xsd:enumeration value="<=">
    <xsd:enumeration value="contains"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="EnumRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
  </xsd:restriction>
</xsd:simpleType>
</xsd:schema>

```

A5.4 Fuzzy LOM filter schema

```

<?xml version="1.0"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  elementFormDefault="qualified" attributeFormDefault="unqualified">
  <xsd:element name="FuzzyQuery">
    <xsd:complexType>
      <xsd:sequence>
        <xsd:element name="FuzzyUterm" type="FuzzyutermDef"
          maxOccurs="unbounded"/>
      </xsd:sequence>
      <xsd:attribute name="type" type="LogicOperand" use="required"/>
      <xsd:attribute name="flag" type="NOT" use="optional"/>
    </xsd:complexType>
  </xsd:element>
  <xsd:complexType name="FuzzyutermDef">
    <xsd:sequence>
      <xsd:element name="FuzzyLterm" type="FuzzyLtermDef"
        maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
  </xsd:complexType>

```

```

    <xsd:attribute name="weight" type="xsd:float" use="required"/>
  </xsd:complexType>
  <xsd:complexType name="FuzzyLtermDef">
    <xsd:sequence>
      <xsd:element name="FuzzyAtom" type="FuzzyAtomType"
maxOccurs="unbounded"/>
    </xsd:sequence>
    <xsd:attribute name="type" type="LogicOperand" use="required"/>
    <xsd:attribute name="flag" type="NOT" use="optional"/>
    <xsd:attribute name="weight" type="xsd:float" use="required"/>
  </xsd:complexType>
  <xsd:complexType name="FuzzyAtomType">
    <xsd:choice>
      <xsd:element name="general_identifier"
type="RelationalExpression_identifier"/>
      <xsd:element name="general_title_string"
type="RelationalExpression_String"/>
      <xsd:element name="general_language" type="RelationalExpression_GL"/>
      <xsd:element name="general_description_string"
type="RelationalExpression_String"/>
      <xsd:element name="general_keyword_string"
type="RelationalExpression_String"/>
      <xsd:element name="general_coverage_string"
type="RelationalExpression_String"/>
      <xsd:element name="general_structure"
type="RelationalExpression_GStructure"/>
      <xsd:element name="general_aggregationLevel_value"
type="RelationalExpression_AggregationlevelValue"/>
      <xsd:element name="lifeCycle_version_string"
type="RelationalExpression_String"/>
      <xsd:element name="lifeCycle_status_value"
type="RelationalExpression_Status"/>
      <xsd:element name="lifeCycle_contribute"
type="RelationalExpression_Contribution"/>
      <xsd:element name="metaMetadata_identifier"
type="RelationalExpression_identifier"/>
      <xsd:element name="metaMetadata_contribute"
type="RelationalExpression_Contribution"/>
      <xsd:element name="metaMetadata_schema"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="metaMetadata_language"
type="RelationalExpression_GL"/>
      <xsd:element name="technical_format"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="technical_size" type="RelationalExpression_TS"/>
      <xsd:element name="technical_location"
type="RelationalExpression_StringWithoutLanguage"/>
      <xsd:element name="technical_requirement_orComposite"
type="RelationalExpression_Trequirement"/>
      <xsd:element name="technical_InstallationRemarks"
type="RelationalExpression_String"/>
      <xsd:element name="technical_OtherPlatformRequirements"
type="RelationalExpression_String"/>
      <xsd:element name="technical_duration_duration"
type="RelationalExpression_Duration"/>
      <xsd:element name="technical_duration_description_string"
type="RelationalExpression_String"/>
      <xsd:element name="educational_interactivityType_value"
type="RelationalExpression_EIT"/>
    </xsd:choice>
  </xsd:complexType>

```

```

    <xsd:element name="educational_learningResourceType_value"
type="RelationalExpression_ELV"/>
    <xsd:element name="educational_interactivityLevel_value"
type="RelationalExpression_EIV"/>
    <xsd:element name="educational_semanticDensity_value"
type="RelationalExpression_ESV"/>
    <xsd:element name="educational_intendedEndUserRole_value"
type="RelationalExpression_ENDUSERROLE"/>
    <xsd:element name="educational_context_value"
type="RelationalExpression_ECV"/>
    <xsd:element name="educational_typicalAgeRange_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_difficulty_value"
type="RelationalExpression_EDV"/>
    <xsd:element name="educational_typicalLearningTime_duration"
type="RelationalExpression_Duration"/>
    <xsd:element name="educational_typicalLearningTime_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="educational_language"
type="RelationalExpression_GL"/>
    <xsd:element name="rights_cost_value"
type="RelationalExpression_CostV"/>
    <xsd:element name="rights_copyrightAndOtherRestrictions_value"
type="RelationalExpression_CostV"/>
    <xsd:element name="rights_description_string"
type="RelationalExpression_String"/>
    <xsd:element name="relation_entry" type="RelationExpression_Relation"/>
    <xsd:element name="annotation_entry"
type="RelationalExpression_Anotation"/>
    <xsd:element name="classification_entry" type="classification_type"/>
  </xsd:choice>
  <xsd:attribute name="flag" type="NOT" use="optional"/>
  <xsd:attribute name="weight" type="xsd:float" use="required"/>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_identifier">
  <xsd:all>
    <xsd:element name="catalog"
type="RelationalExpression_StringWithoutLanguage"/>
    <xsd:element name="entry"
type="RelationalExpression_StringWithoutLanguage"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_GStructure">
  <xsd:simpleContent>
    <xsd:extension base="GStructure">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="GStructure">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="atomic"/>
    <xsd:enumeration value="collection"/>
    <xsd:enumeration value="networked"/>
    <xsd:enumeration value="hierarchical"/>
    <xsd:enumeration value="linear"/>
  </xsd:restriction>

```

```

    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_AggregationlevelValue">
    <xsd:simpleContent>
      <xsd:extension base="AggregationlevelValue">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:simpleType name="AggregationlevelValue">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="1"/>
      <xsd:enumeration value="2"/>
      <xsd:enumeration value="3"/>
      <xsd:enumeration value="4"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_Version">
    <xsd:simpleContent>
      <xsd:extension base="Version">
        <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:simpleType name="Version">
    <xsd:restriction base="xsd:string">
      <xsd:pattern value="([0-9]+)|([0-9]+\.[0-9]+)"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_Status">
    <xsd:simpleContent>
      <xsd:extension base="Status">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:simpleType name="Status">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="draft"/>
      <xsd:enumeration value="final"/>
      <xsd:enumeration value="revised"/>
      <xsd:enumeration value="unavailable"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_Contribution">
    <xsd:all>
      <xsd:element name="role_value" type="RelationalExpression_CR"
minOccurs="0"/>
      <xsd:element name="entity"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
      <xsd:element name="date_dateTime" type="RelationalExpression_DateTime"
minOccurs="0"/>
      <xsd:element name="date_description_string"
type="RelationalExpression_String" minOccurs="0"/>
    </xsd:all>
  </xsd:complexType>

```

```

<xsd:complexType name="RelationExpression_Rresource">
  <xsd:all>
    <xsd:element name="identifier" type="RelationalExpression_identifier"
minOccurs="0"/>
    <xsd:element name="description_string"
type="RelationalExpression_String" minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Anotation">
  <xsd:all>
    <xsd:element name="annotation_entity"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
    <xsd:element name="annotation_date_dateTime"
type="RelationalExpression_DateTime" minOccurs="0"/>
    <xsd:element name="annotation_description_string"
type="RelationalExpression_String" minOccurs="0"/>
    <xsd:element name="annotation_date_description_string"
type="RelationalExpression_String" minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationExpression_Relation">
  <xsd:all>
    <xsd:element name="kind_value" type="RelationalExpression_RKV"
minOccurs="0"/>
    <xsd:element name="relation_resource"
type="RelationExpression_Rresource" minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="classification_type">
  <xsd:all>
    <xsd:element name="purpose_value" type="RelationalExpression_CPV"
minOccurs="0"/>
    <xsd:element name="taxonPathEntry"
type="RelationalExpression_taxonPath" minOccurs="0"/>
    <xsd:element name="description_string"
type="RelationalExpression_String" minOccurs="0"/>
    <xsd:element name="keyword_string" type="RelationalExpression_String"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_taxonPath">
  <xsd:all>
    <xsd:element name="source_string" type="RelationalExpression_String"
minOccurs="0"/>
    <xsd:element name="taxon_entry" type="RelationalExpression_taxon"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_taxon">
  <xsd:all>
    <xsd:element name="id"
type="RelationalExpression_StringWithoutLanguage" minOccurs="0"/>
    <xsd:element name="entry_string" type="RelationalExpression_String"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Trequirement">
  <xsd:all>
    <xsd:element name="type_value" type="RelationalExpression_TV"

```

```

minOccurs="0"/>
  <xsd:element name="name_value" type="RelationalExpression_NV"
minOccurs="0"/>
  <xsd:element name="maximumVersion" type="RelationalExpression_Version"
minOccurs="0"/>
  <xsd:element name="minimumVersion" type="RelationalExpression_Version"
minOccurs="0"/>
  </xsd:all>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_DateTime">
  <xsd:simpleContent>
    <xsd:extension base="xsd:dateTime">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_Duration">
  <xsd:simpleContent>
    <xsd:extension base="xsd:duration">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_CostV">
  <xsd:simpleContent>
    <xsd:extension base="CostV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="CostV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="yes"/>
    <xsd:enumeration value="no"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_StringWithoutLanguage">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_TS">
  <xsd:simpleContent>
    <xsd:extension base="TS">
      <xsd:attribute name="op" type="NumberRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="TS">
  <xsd:restriction base="xsd:string">
    <xsd:pattern value="[0-9] +"/>
  </xsd:restriction>

```



```

</xsd:simpleType>
<xsd:complexType name="RelationalExpression_CPV">
  <xsd:simpleContent>
    <xsd:extension base="CPV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="CPV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="discipline"/>
    <xsd:enumeration value="idea"/>
    <xsd:enumeration value="prerequisite"/>
    <xsd:enumeration value="educational objective"/>
    <xsd:enumeration value="accessibility"/>
    <xsd:enumeration value="restrictions"/>
    <xsd:enumeration value="educational level"/>
    <xsd:enumeration value="skill level"/>
    <xsd:enumeration value="security level"/>
    <xsd:enumeration value="competency"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_CTES">
  <xsd:simpleContent>
    <xsd:extension base="xsd:string">
      <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:complexType name="RelationalExpression_MetaCRV">
  <xsd:simpleContent>
    <xsd:extension base="MetaCRV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="MetaCRV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="creator"/>
    <xsd:enumeration value="validator"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_RKV">
  <xsd:simpleContent>
    <xsd:extension base="RKV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="RKV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="ispartof"/>
    <xsd:enumeration value="haspart"/>
    <xsd:enumeration value="isversionof"/>
    <xsd:enumeration value="hasversion"/>
  </xsd:restriction>
</xsd:simpleType>

```

```

    <xsd:enumeration value="isformatof"/>
    <xsd:enumeration value="hasformat"/>
    <xsd:enumeration value="references"/>
    <xsd:enumeration value="isreferencedby"/>
    <xsd:enumeration value="isbasedon"/>
    <xsd:enumeration value="isbasisfor"/>
    <xsd:enumeration value="requires"/>
    <xsd:enumeration value="isrequiredby"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EDV">
  <xsd:simpleContent>
    <xsd:extension base="EDV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EDV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very easy"/>
    <xsd:enumeration value="easy"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="difficult"/>
    <xsd:enumeration value="very difficult"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ECV">
  <xsd:simpleContent>
    <xsd:extension base="ECV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ECV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="school"/>
    <xsd:enumeration value="higher education"/>
    <xsd:enumeration value="training"/>
    <xsd:enumeration value="other"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ENDUSERROLE">
  <xsd:simpleContent>
    <xsd:extension base="ENDUSERROLE">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ENDUSERROLE">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="teacher"/>
    <xsd:enumeration value="author"/>
    <xsd:enumeration value="learner"/>
    <xsd:enumeration value="manager"/>
  </xsd:restriction>
</xsd:simpleType>

```

```

<xsd:complexType name="RelationalExpression_ESV">
  <xsd:simpleContent>
    <xsd:extension base="ESV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ESV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very low"/>
    <xsd:enumeration value="low"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="high"/>
    <xsd:enumeration value="very high"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EIV">
  <xsd:simpleContent>
    <xsd:extension base="EIV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EIV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="very low"/>
    <xsd:enumeration value="low"/>
    <xsd:enumeration value="medium"/>
    <xsd:enumeration value="high"/>
    <xsd:enumeration value="very high"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_ELV">
  <xsd:simpleContent>
    <xsd:extension base="ELV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="ELV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="exercise"/>
    <xsd:enumeration value="simulation"/>
    <xsd:enumeration value="questionnaire"/>
    <xsd:enumeration value="diagram"/>
    <xsd:enumeration value="figure"/>
    <xsd:enumeration value="graph"/>
    <xsd:enumeration value="index"/>
    <xsd:enumeration value="slide"/>
    <xsd:enumeration value="table"/>
    <xsd:enumeration value="narrative text"/>
    <xsd:enumeration value="exam"/>
    <xsd:enumeration value="experiment"/>
    <xsd:enumeration value="problem statement"/>
    <xsd:enumeration value="self assessment"/>
    <xsd:enumeration value="lecture"/>
  </xsd:restriction>
</xsd:simpleType>

```

```

    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_GL">
    <xsd:simpleContent>
      <xsd:extension base="GL">
        <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:complexType name="RelationalExpression_String">
    <xsd:simpleContent>
      <xsd:extension base="xsd:string">
        <xsd:attribute name="op" type="StringRelationalOperator"
use="required"/>
        <xsd:attribute name="language" type="GL" use="optional"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:simpleType name="GL">
    <xsd:restriction base="xsd:string">
      <xsd:pattern value="([a-zA-Z]+) | ([a-zA-Z]+(-) [A-Za-z]+)"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_CR">
    <xsd:simpleContent>
      <xsd:extension base="CR">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>
  <xsd:simpleType name="CR">
    <xsd:restriction base="xsd:string">
      <xsd:enumeration value="author"/>
      <xsd:enumeration value="publisher"/>
      <xsd:enumeration value="unknown"/>
      <xsd:enumeration value="initiator"/>
      <xsd:enumeration value="terminator"/>
      <xsd:enumeration value="validator"/>
      <xsd:enumeration value="editor"/>
      <xsd:enumeration value="graphical designer"/>
      <xsd:enumeration value="technical implementer"/>
      <xsd:enumeration value="content provider"/>
      <xsd:enumeration value="technical validator"/>
      <xsd:enumeration value="educational validator"/>
      <xsd:enumeration value="script writer"/>
      <xsd:enumeration value="instructional designer"/>
      <xsd:enumeration value="subject matter expert"/>
    </xsd:restriction>
  </xsd:simpleType>
  <xsd:complexType name="RelationalExpression_TV">
    <xsd:simpleContent>
      <xsd:extension base="TV">
        <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
      </xsd:extension>
    </xsd:simpleContent>
  </xsd:complexType>

```

```

<xsd:simpleType name="TV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="operating system"/>
    <xsd:enumeration value="browser"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_NV">
  <xsd:simpleContent>
    <xsd:extension base="NV">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="NV">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="pc-dos"/>
    <xsd:enumeration value="ms-windows"/>
    <xsd:enumeration value="macos"/>
    <xsd:enumeration value="unix"/>
    <xsd:enumeration value="multi-os"/>
    <xsd:enumeration value="none"/>
    <xsd:enumeration value="any"/>
    <xsd:enumeration value="netscape"/>
    <xsd:enumeration value="communicator"/>
    <xsd:enumeration value="ms-internet explorer"/>
    <xsd:enumeration value="opera"/>
    <xsd:enumeration value="amaya"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:complexType name="RelationalExpression_EIT">
  <xsd:simpleContent>
    <xsd:extension base="EIT">
      <xsd:attribute name="op" type="EnumRelationalOperator"
use="required"/>
    </xsd:extension>
  </xsd:simpleContent>
</xsd:complexType>
<xsd:simpleType name="EIT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="active"/>
    <xsd:enumeration value="expositive"/>
    <xsd:enumeration value="mixed"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="LogicOperand">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="or"/>
    <xsd:enumeration value="and"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="NOT">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="not"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="NumberRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value=">"/>

```

```
<xsd:enumeration value="&lt;"/>
<xsd:enumeration value="!=">
<xsd:enumeration value="=">
<xsd:enumeration value=">=">
<xsd:enumeration value="&lt;=">
</xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="StringRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value="&gt;"/>
    <xsd:enumeration value="&lt;"/>
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
    <xsd:enumeration value=">=">
    <xsd:enumeration value="&lt;=">
    <xsd:enumeration value="contains"/>
  </xsd:restriction>
</xsd:simpleType>
<xsd:simpleType name="EnumRelationalOperator">
  <xsd:restriction base="xsd:token">
    <xsd:enumeration value="=">
    <xsd:enumeration value="!=">
  </xsd:restriction>
</xsd:simpleType>
</xsd:schema>
```

Appendix 6: Personalization implementation in LOGOS – Example XML Documents

A6.1 Example of input parameters to the createPersExperience or createDynAssessment service (InputParameters_middleware.xml)

```
<?xml version="1.0" encoding="utf-8"?>
<personalizationParameters xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance" xsi:noNamespaceSchemaLocation="personalizationParameters.xsd">
  <pedagogicalPreferences>
    <!-- Educational level and difficulty are defined from the Learner for
each Learning Experience request -->
    <educ_diff priority="1">
      <level>Further</level>
      <difficulty>difficult</difficulty>
    </educ_diff>

    <!-- The Learner's Learning Style -->
    <learningStyle>ExampleOriented</learningStyle>

    <!-- All the previous knowledge of the Learner regarding the specific
domain
(Bulgarian Iconography, ontology:icons-stable-061107.xml) -->
    <!-- The targeting Learning Objectives of the Learner are marked as
selected="true". Those that the generated learning experience should cover.
-->
    <learningObjectives>
      <!-- Each learning objective has a priority (defined by Learner if
(s)he wants) and a satisfaction status updated by the LMS using for example
the score of the Learner in the corresponding Assessment Objects (same
learning objective). The middleware can be based on the priority or the
status (according to the preference of the Learner) in order to construct
the learning experience. -->
      <learningObjective priority="0.7" status="0.3" selected="true">
        <!-- The verb of the learning objective -->
        <verb>comprehend</verb>
        <!-- The domain of the learning objective(Bulgarian Iconography,
ontology:icons-stable-061107.xml)-->
        <source>icons-stable-061107.xml</source>
        <!-- The topic of the learning objective (class#individual) -->
        <topic>Iconographic School#Bansko-Razlog School of Art</topic>
      </learningObjective>

      <learningObjective priority="0.9" status="0.6">
        <verb>describe</verb>
        <source>icons-stable-061107.xml</source>
        <topic>Iconographic School#Bansko-Razlog School of Art</topic>
      </learningObjective>

      <learningObjective priority="0.9" status="0.4" selected="true">
        <verb>compare</verb>
        <source>icons-stable-061107.xml</source>
        <topic>Image of Hierarch#Saint Nicholas</topic>
      </learningObjective>
    </learningObjectives>

    <!--preferred planner (optional element, multiple planners can be
```

```

declared): the person who develops Learning Designs-->
  <planner>Polyxeni Arapi</planner>
</pedagogicalPreferences>

<contentPreferences>
<!-- Preferred Language of the learning experience -->
<language>en</language>
<!-- Learner devices -->
<!-- In fact as things are now there is no need to use the device info. -
->
  <devices>
    <device>PC</device>
    <device>mobile</device>
  </devices>
<!-- Preferred provider (e.g. author) of LOs (one or more)-->
<learningProviders>
  <learningProvider>Polyxeni Arapi</learningProvider>
  <learningProvider>Manolis Mylonakis</learningProvider>
</learningProviders>
</contentPreferences>

<!-- A learning objective with status>threshold is considered as satisfied
and there won't be such activities
in the final learning experience associated with this objective -->
  <threshold>0.5</threshold>
</personalizationParameters>

```

A6.2 Example of XML Document returned by the service createDynAssessment for the dynamic creation of Assessments (DynamicAssessmentExample.xml)

```

<?xml version="1.0"?>
<DynamicAssessment>
  <AssessmentObject ID="69c134e7-a71a-11dc-8497-a390db441d3b" TYPE="AIO"/>
  <AssessmentObject ID="ccf6cd84-e45d-11dc-acf0-b5d44c3f1daa" TYPE="ATO"/>
  <AssessmentObject ID="99a7f7dc-896f-11dd-af22-1bfbe454fa36" TYPE="AIO"/>
</DynamicAssessment>

```

A6.3 Example of XML Document returned by the get_All_LD_in_Domain service (LDsInDomainExample.xml)

```

<?xml version="1.0"?>
<learningDesigns xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="learningDesignsInDomain.xsd">

  <training id="T120108115645">
    <title>Bansko-Razlog Iconographic School of Art</title>
    <description>Bansko-Razlog Iconographic School of Art description, famous
iconographers and themes.</description>
    <planner>Polyxeni Arapi</planner>
    <trainingMethod id="TM120108132630">
      <learningStyle>
        <source>http://somehost/learningstyles.owl</source>
        <value>ExampleOriented</value>
      </learningStyle>
    </trainingMethod>
  </training>

```



```

    <educationalLevel>
      <source>http://somehost/educationallevels.owl</source>
      <value>Further</value>
    </educationalLevel>
    <difficulty>medium</difficulty>
  </trainingMethod>
<trainingMethod id="TM120108132631">
  <learningStyle>
    <source>http://somehost/learningstyles.owl</source>
    <value>GeneralToSpecific</value>
  </learningStyle>
  <educationalLevel>
    <source>http://somehost/educationallevels.owl</source>
    <value>Further</value>
  </educationalLevel>
  <difficulty>medium</difficulty>
</trainingMethod>
</training>

<training id="T120108115845">
  <title>X Iconographic School of Art</title>
  <description>The history of the X Iconographic School of
Art</description>
  <planner>Nektarios Moumoutzis</planner>
  <trainingMethod id="TM120108132830">
    <learningStyle>
      <source>http://somehost/learningstyles.owl</source>
      <value>GeneralToSpecific</value>
    </learningStyle>
    <educationalLevel>
      <source>http://somehost/educationallevels.owl</source>
      <value>Primary</value>
    </educationalLevel>
    <difficulty>medium</difficulty>
  </trainingMethod>
</training>
</learningDesigns>

```

Appendix 7: 3DE Project Questionnaire

Age:	17-24 <input type="checkbox"/>	25-34 <input type="checkbox"/>	35-44 <input type="checkbox"/>	45-59 <input type="checkbox"/>	More than 59 <input type="checkbox"/>
Gender	F <input type="checkbox"/>			M <input type="checkbox"/>	
Education	High school <input type="checkbox"/>	Degree at University <input type="checkbox"/>	Master <input type="checkbox"/>	Professional training <input type="checkbox"/>	Continuing education <input type="checkbox"/>
Field	Technology		Business and Administration		Social & Health & Medicine
	Humanities		Arts		Agriculture
	Science		Architecture		Other
Home Country	Finland <input type="checkbox"/>	France <input type="checkbox"/>	Italy <input type="checkbox"/>	Spain <input type="checkbox"/>	
Are you studying now?	In a university course <input type="checkbox"/>			With continuing education <input type="checkbox"/>	
Are you working now?	Yes <input type="checkbox"/>			No <input type="checkbox"/>	

Check the answer that better fit your opinion. Use the table reported after the test to calculate your score.

1 = I totally disagree

2 = I partly disagree

3 = I partly agree

4 = I totally agree

	1	2	3	4
I am eager to test new ideas in practice.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like to plan my work properly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't believe in impulsive decisions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I act spontaneously.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I believe mainly in practical facts.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like the company of sociable people.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I want to see the connections between theory and practice immediately.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I tend to rely on principles and theories.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I prefer having lots of drafts before making the final version.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I usually say immediately what I think in order to achieve results quickly.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't comment before I've thought things through.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I get bored with routines.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I want to consider all information carefully before making any decisions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I try to consider things in their logical context.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I find new experiences interesting.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I'm always a very practical person.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I work out my thoughts before I express them.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like to take several points of view into consideration before deciding my own.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Straight action is more typical for me than careful.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I tend to produce innovative ideas.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I tend to get straight to the point in the meetings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't act without proper planning.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like to work in detail before coming to a conclusion.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I always prefer a systematic way of working.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I work analytically when solving problems.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I don't hide my feelings.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I work effectively to see the practical results.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I avoid making hasty conclusions.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I'm interested in putting ideas into practice.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I tend to organise my thoughts well.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I seek theoretical principles behind things and events.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am usually the innovative person in the social situations.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I like talking more than listening.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Scientifically proved theories interest me.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I find it difficult to be spontaneous.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
I am open to use any efficient method to reach results.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Score table for the calculation of the learning style

To get test result, fill in the following table. The answers 1 e 2 get 0 point, answer 3 get 1 point, answer 4 get 2 points.

Ex.: if to question 17 you answered "I partly agree" (answer 3) yu get 1 point, in the table below put 1 near number 17 in the column "Reflector".

Then calculate the total for each column and find out your learning style preferences.

In the following you will find the explanations about the four learning styles.

Activist		Reflector		Theorist		Pragmatist	
4	= _____	2	= _____	3	= _____	1	= _____
6	= _____	9	= _____	8	= _____	5	= _____
12	= _____	11	= _____	14	= _____	7	= _____
15	= _____	13	= _____	24	= _____	10	= _____
19	= _____	17	= _____	25	= _____	16	= _____
20	= _____	18	= _____	30	= _____	21	= _____
26	= _____	22	= _____	31	= _____	27	= _____
32	= _____	23	= _____	34	= _____	29	= _____
33	= _____	28	= _____	35	= _____	36	= _____
Total: _____		_____		_____		_____	

Learning style THEORIST

In theorist learning style, high scores in reflective observation on processing continuum correlate with high scores in abstract conceptualization on perception continuum.

Theorists learn best when things to be learned are part of a system, model, concept or theory. They need time to methodologically explore the associations and interrelationships between ideas, events and situations; they need to have a chance to probe the basic methodology, assumptions and the logic behind things. Theorists like to analyze complex situations and be in structured situations with clear purposes. They also learn best when they can listen to or read about ideas and concepts that emphasize rationality or logic and are well argued. Analyzing and then generalizing the reasons for success and failure appeal theorists. It is advantageous to offer interesting ideas to theorists, even if they are not immediately relevant and to require them to understand and participate in complex situations.

Theorists may react against learning activities where they have to do something without apparent purpose or context. They usually don't want to participate in situations that emphasize emotions and feelings. Theorists don't like to be involved in unstructured activities with high ambiguity and uncertainty and they don't like to be asked to act or decide without a basis in policy, principle or concept. Disarray of alternative or contradictory techniques and methods without deep exploring is not appropriate for theorists and they react against if the subject matter is not methodologically sound, e.g. the questionnaires aren't validated, or if they find it platitudinous or shallow. Theorists feel out of tune with other participants in the learning activities, especially if they are less advanced in the subject.

Learning activities that suit theorists:

- What is to be learned is part of a system, model, concept or theory
- Exploring the associations and interrelationships between ideas, events and situations.
- Question and answering session, checking a paper for inconsistencies.
- Analysing a complex situation, being tested in a tutorial session, teaching advanced people.
- Structured situations with clear purposes.
- Listening / reading about well argued ideas and concepts that emphasize rationality.

- Analysing and then generalising the reasons for success or failure.
- Understanding and participating complex situations

Learning style REFLECTOR

In reflector learning style, high scores in reflective observation on processing continuum correlate with high scores in concrete experience on perception continuum.

Reflectors learn best when they are allowed or encouraged to watch, think or chew over activities. They like to stand back from events and observe and think before they act, because they need time to assimilate things before commenting. They also like to do some painstaking research, assemble information to get to the bottom of things and produce carefully considered analyses and reports. It is good for reflectors to review what's happened and what they've learned and to have time to reach a decision without a pressure and deadlines. Reflectors' learning can be aided by helping them to exchange views with other people within a structured learning experience.

Reflectors may react against learning activities, where they have to be in the limelight, e.g. as a chairman or a role-player. They don't like to be involved in situations that require action without planning or to be forced to do or decide something without proper planning and sufficient data. Pronounced instructions of how things should be done do not appeal reflectors and they don't like to make short cuts or to do a superficial job.

Learning activities that suit reflectors:

- Watching / thinking / chewing over activities
Observing, watching a film / TV.
- Thinking before acting: time to prepare, chance to read in advance, brief giving background. data...
- Investigating, assembling information (with no pressure or tight deadlines).
- Analyses and reports.
- Exchanging views with other people by prior agreement or within a structured learning experience.

Learning style PRAGMATIST

In pragmatist learning style, high scores in active experiment on processing continuum correlate with high scores in abstract conceptualization experience on perception continuum.

Pragmatists learn best when they are offered obvious links between the subject matter and a problem or opportunity on the job. They like to be shown techniques for doing things with obvious practical advantages, for example how to save time. Pragmatists enjoy a chance to try out or practice techniques with feedback from an expert or a possibility to emulate them. Immediate opportunity to implement the learnt things is very important to pragmatists and they prefer to concentrate on practical issues.

Pragmatists may react against learning activities where they can't see the immediate relevance or practical benefit. They don't like if the organisers of learning or the event itself seem distant from reality or there is no practice or clear instructions on how to do things. The sufficient rewards from the learning should always be able to be seen for the pragmatists, e.g. more sales etc.

Learning activities that suit pragmatists:

- Showing techniques for doing things with obvious practical advantages: e.g. how to save time.
- Trying out and practising techniques with feedback from an expert
- Emulating a person, a demonstration, examples, anecdotes, films.
- Opportunities to implement what has just been learnt.
- High face validity, e.g. real problems.
- Drawing up action plans with an obvious end product, suggesting short cuts, giving tips.

Learning style ACTIVIST

In activist learning style high scores in active experiment on processing continuum correlate with high scores in concrete experience on perception continuum.

People with activist learning style learn best when they are offered new experiences, problems and opportunities from which to learn. They like when things chop and change and therefore short activities, such as business games, competitive teamwork tasks and role-playing, are suitable for them. Activists also learn well when they have high visibility

e.g. as a chairman, challenging tasks and they are allowed to generate ideas without constraints. Solving problems as part of a team suits activists well, because they like to be involved with other people.

Activists may react against learning activities where they have a passive role, like listening to lectures, and they can't self be involved. They don't like tasks where they have to assimilate, analyse and interpret lots of messy data or they have to engage in solitary work, like reading, writing or thinking on their own. Assessing beforehand what they will learn and appraising afterwards what they have learned is also unfamiliar to activists. They don't prefer repeating essentially the same activity over and over again while practicing or having precise instructions with little room for manoeuvre.

Learning activities that suit activists:

- New experiences / problems / opportunities.
- Teamwork
- Business games, competitive teamwork tasks, role-playing exercises.
- Diverse activities to tackle.
- Discussion leading, chairmanship, presentations.

Appendix 8: Ontology describing the LOGOS domain in CogXML

In this Annex, an ontology describing the LOGOS Project domain is presented that has been used in the experimentation and evaluation phase of the personalization framework. The ontology has been developed with CoGUI (Ontology Editor) and represented in CogXML. The CoGXML format allows representation of conceptual graphs in the format of XML documents.

```
<?xml version="1.0" encoding="UTF-8"?>
<cogxml>
  <support name="vocabulary">
    <conceptTypes>
      <ctype id="_ct0" label="LOGOS Project">
        <translation descr="" label="LOGOS Project" lang="en"/>
      </ctype>
      <ctype id="_ANNOTATION" label="_ANNOTATION">
        <translation descr="" label="_ANNOTATION" lang="en"/>
      </ctype>
      <ctype id="_ct2" label="LOGOS Platform">
        <translation descr="" label="LOGOS Platform" lang="en"/>
      </ctype>
      <ctype id="_ct3" label="Objects Repository">
        <translation descr="" label="Objects Repository" lang="en"/>
      </ctype>
      <ctype id="_ct4" label="DO Repository">
        <translation descr="" label="DO Repository" lang="en"/>
      </ctype>
      <ctype id="_ct5" label="LO Repository">
        <translation descr="" label="LO Repository" lang="en"/>
      </ctype>
      <ctype id="_ct6" label="CO Repository">
        <translation descr="" label="CO Repository" lang="en"/>
      </ctype>
      <ctype id="_ct7" label="Learning Management System - LMS">
        <translation descr="" label="Learning Management System - LMS"
lang="en"/>
      </ctype>
      <ctype id="_ct8" label="Authoring Studio">
        <translation descr="" label="Authoring Studio" lang="en"/>
      </ctype>
      <ctype id="_ct9" label="AO Repository">
        <translation descr="" label="AO Repository" lang="en"/>
      </ctype>
      <ctype id="_ct10" label="Object">
        <translation descr="" label="Object" lang="en"/>
      </ctype>
      <ctype id="_ct11" label="Digital Object - DO">
        <translation descr="" label="Digital Object - DO" lang="en"/>
      </ctype>
      <ctype id="_ct12" label="Learning Object - LO">
        <translation descr="" label="Learning Object - LO" lang="en"/>
      </ctype>
      <ctype id="_ct13" label="Courseware Object - CO">
        <translation descr="" label="Courseware Object - CO" lang="en"/>
      </ctype>
      <ctype id="_ct14" label="Authoring Tool">
        <translation descr="" label="Authoring Tool" lang="en"/>
      </ctype>
    </conceptTypes>
  </support>
</cogxml>
```

```

    </ctype>
    <ctype id="_ct15" label="Ontology Management Tool - OMT">
      <translation descr="" label="Ontology Management Tool - OMT"
lang="en"/>
    </ctype>
    <ctype id="_ct16" label="Content Description Tool - CDT">
      <translation descr="" label="Content Description Tool - CDT"
lang="en"/>
    </ctype>
    <ctype id="_ct17" label="Description Tool for Learning Objects - DTLO">
      <translation descr="" label="Description Tool for Learning Objects -
DTLO" lang="en"/>
    </ctype>
    <ctype id="_ct18" label="Courseware Object Editor - COE">
      <translation descr="" label="Courseware Object Editor - COE"
lang="en"/>
    </ctype>
    <ctype id="_ct19" label="Media Server">
      <translation descr="" label="Media Server" lang="en"/>
    </ctype>
    <ctype id="_ct20" label="Assessment Object - AO">
      <translation descr="" label="Assessment Object - AO" lang="en"/>
    </ctype>
    <ctype id="_ct21" label="Assessment Item Object - AIO">
      <translation descr="" label="Assessment Item Object - AIO" lang="en"/>
    </ctype>
    <ctype id="_ct22" label="Assessment Test Object - ATO">
      <translation descr="" label="Assessment Test Object - ATO" lang="en"/>
    </ctype>
    <ctype id="_ct23" label="Publishing Tool - PT">
      <translation descr="" label="Publishing Tool - PT" lang="en"/>
    </ctype>
    <ctype id="_ct24" label="Learning Design Editor - LDE">
      <translation descr="" label="Learning Design Editor - LDE" lang="en"/>
    </ctype>
    <ctype id="_ct25" label="Manual">
      <translation descr="" label="Manual" lang="en"/>
    </ctype>
    <ctype id="_ct26" label="Tutorial">
      <translation descr="" label="Tutorial" lang="en"/>
    </ctype>
    <ctype id="_ct27" label="Walkthrough">
      <translation descr="" label="Walkthrough" lang="en"/>
    </ctype>
    <ctype id="_ct28" label="Learning Design">
      <translation descr="" label="Learning Design" lang="en"/>
    </ctype>
    <ctype id="_ct29" label="Installer">
      <translation descr="" label="Installer" lang="en"/>
    </ctype>
    <ctype id="_ct30" label="User Role">
      <translation descr="" label="User Role" lang="en"/>
    </ctype>
    <ctype id="_ct31" label="Knowledge Manager">
      <translation descr="" label="Knowledge Manager" lang="en"/>
    </ctype>
    <ctype id="_ct32" label="Annotator - Indexer">
      <translation descr="" label="Annotator - Indexer" lang="en"/>
    </ctype>

```

```

<ctype id="_ct33" label="Educationalist">
  <translation descr="" label="Educationalist" lang="en"/>
</ctype>
<ctype id="_ct34" label="Learning Designer">
  <translation descr="" label="Learning Designer" lang="en"/>
</ctype>
<ctype id="_ct35" label="Courseware Developer">
  <translation descr="" label="Courseware Developer" lang="en"/>
</ctype>
<ctype id="_ct36" label="Learner">
  <translation descr="" label="Learner" lang="en"/>
</ctype>
<ctype id="_ct37" label="Dynamic Courseware Creation Middleware">
  <translation descr="" label="Dynamic Courseware Creation Middleware"
lang="en"/>
</ctype>
<ctype id="_ct38" label="Media">
  <translation descr="" label="Media" lang="en"/>
</ctype>
<ctype id="_ct39" label="Document">
  <translation descr="" label="Document" lang="en"/>
</ctype>
<ctype id="_ct40" label="Image">
  <translation descr="" label="Image" lang="en"/>
</ctype>
<ctype id="_ct41" label="Video">
  <translation descr="" label="Video" lang="en"/>
</ctype>
<ctype id="_ct42" label="Learner Profile">
  <translation descr="" label="Learner Profile" lang="en"/>
</ctype>
<ctype id="_ct43" label="Device">
  <translation descr="" label="Device" lang="en"/>
</ctype>
<ctype id="_ct44" label="PC">
  <translation descr="" label="PC" lang="en"/>
</ctype>
<ctype id="_ct45" label="DVB-MHP">
  <translation descr="" label="DVB-MHP" lang="en"/>
</ctype>
<ctype id="_ct46" label="Mobile">
  <translation descr="" label="Mobile" lang="en"/>
</ctype>
<ctype id="_ct47" label="Course">
  <translation descr="" label="Course" lang="en"/>
</ctype>
<ctype id="_ct48" label="Courseware">
  <translation descr="" label="Courseware" lang="en"/>
</ctype>
<ctype id="_ct49" label="Static Courseware">
  <translation descr="" label="Static Courseware" lang="en"/>
</ctype>
<ctype id="_ct50" label="Personalized Courseware">
  <translation descr="" label="Personalized Courseware" lang="en"/>
</ctype>
<ctype id="_ct51" label="Static Course">
  <translation descr="" label="Static Course" lang="en"/>
</ctype>
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x="160" y="510">
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    </rtype>
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x="310" y="410">
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x="310" y="510">
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x="160" y="870">
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y="100">
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