INSTITUTE OF MATHEMATICS AND INFORMATICS
BULGARIAN ACADEMY OF SCIENCES

Supporting Personalized Learning Experiences on top of Multimedia Digital Libraries

by

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A dissertation submitted for the award of educational and scientific degree "Doctor of Philosophy" in the professional field 4.6 "Informatics and Computer Science" PhD program on Informatics

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Sofia, 2017

Preface

Mrs. Polyxeni Arapi holds a Diploma (5-years program) in Electronic and Computer Engineering from the Electronic and Computer Engineering School of the Technical University of Crete from where she graduated in 2003. Her Diploma Thesis proposing and implementing original solutions and mechanisms for extending existing eLearning systems to support interoperability using SCORM standard was one of the first attempts in this area and has been awarded by the Technical Chamber of Greece as the best Diploma Thesis in the profession of Electronic Engineers in 2003, while her first paper in this year in IEEE ICALT conference presenting those solutions has received more than 30 citations. Mrs. Arapi also holds a M.Sc. in Electronic and Computer Engineering from the Electronic and Computer Engineering School of the Technical University of Crete. She has been working as a researcher in the Laboratory of Distributed Multimedia Information Systems and Applications (TUC/MUSIC) since 2002 involved in many European Research and Development projects related with eLearning and digital libraries. Since 2006 she belongs to the permanent laboratory technical and teaching staff of the Electronic and Computer Engineering School of the Technical University of Crete and is the technical coordinator of the Laboratory of Software Technology and Network Applications (SoftNet), administrating among others its large infrastructure.

Mrs. Arapi has participated as senior researcher in the following European Research and Development projects of the Laboratory of Distributed Multimedia Information Systems and Applications related with eLearning and digital libraries: LdV/ADONIS (Advanced on-the-job e-training solutions in e-business for SMEs), LdV/KNOSOS (New media knowledge village for innovative e-learning solutions), IST/DELOS II (IST Network of Excellence in Digital Libraries), LdV/CHIRON (Referring Innovative Technologies and Solutions for Ubiquitous Learning), IST STREP/LOGOS (Knowledge-on-Demand for Ubiquitous Learning), LLL/iQTool (Innovative eLearning Tool for Quality Training Material in VET), LdV TOI/Organic.Mednet (Developing the Skills of Organic Agriculture Trainers for the Mediterranean), FP7 ICT-PSP/Natural Europe (Natural History & Environmental Cultural Heritage in European Digital Libraries for Education), FP7 ICT-PSP/Open Discovery Space (A socially-powered and multilingual open learning infrastructure to boost the adoption of eLearning resources), LdV QONIAon (VET Qualification Practice for eInclusion), ECHO/EVANDE (Enhancing Volunteer Awareness and education against Natural Disasters through E-learning), Erasmus+/MechMate (Strategic Partnership in the field of Mechatronics for innovative and smart growth of European manufacturing SMEs). In several of them was technical coordinator and among the authors of their proposals.

Several of these projects (ADONIS, KNOSOS, CHIRON, LOGOS, QONIAon) were common projects with the Institute of Mathematics and Informatics (IMI-BAS) and the Laboratory of Telematics (LT-BAS) of the Bulgarian Academy of Sciences.

Starting from DELOS project, Mrs. Arapi has been working on challenges and issues related with digital libraries and eLearning systems interoperability and personalization for more than ten years. Her more recent research focuses on accessing cultural digital collections residing in institutions preserving cultural heritage and their re-purposing to support effective learning applications on top of them taking into account pedagogy aspects and approaches for the development of personalized learning experiences to fit different learners' needs and preferences. Results from the research she has performed in a number of European Research & Development projects (e.g. IST/STREP LOGOS, ICT/PSP Natural Europe, ICT/PSP Open Discovery Space) were combined, enriched, specialized and applied in the PhD thesis for the domain of cultural digital libraries in the context of Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018), funded by the Bulgarian Sciences Fund.

Acknowledgements

I would like to express my gratitude to my scientific advisors Prof. PhD Radoslav Pavlov and Assoc. Prof. PhD Radoslav Yoshinov for their supervision, guidance, and support throughout my research and PhD thesis procedure, and our excellent collaboration and experiences in the context of all European Research & Developement projects we have been working together for more than 20 years. Special thanks to Assoc. Prof. PhD Desislava Paneva-Marinova for her help and support throughout the whole PhD thesis procedure and Assoc. Prof. PhD Danail Dochev for his review. Also, I would like to thank Mr. Dimitar Sholev for the translation of my PhD thesis executive summary into Bulgarian and Mrs. Monka Kotseva and Mrs. Maya Tomova for their help in preparing all the required documents following my PhD thesis for completing the procedure. Moreover, I would like to thank all the staff of Institute of Mathematics and Informatics (IMI-BAS) and Laboratory of Telematics (LT-BAS) for their positive and warm attitude and support in the whole procedure.

I would like to also thank Prof. Emeritus Stavros Christodoulakis, former director of the Laboratory of Distributed Multimedia Information Systems and Applications (MUSIC) of the Technical University of Crete for our excellent long collaboration and experiences in the context of many European Research & Development projects, where among others I performed research which was enriched, exploited and applied in this PhD thesis. I would also like to acknowledge my colleagues in MUSIC lab and in LOGOS and Natural Europe projects who implemented components of the framework and architecture presented in this thesis.

I would also like to thank in advance the readers and reviewers of this thesis for the time they devoted and their critical evaluation and helpful comments on my thesis.

Finally, I would like to thank my family and friends for their invaluable support not only during my research but in all aspects of my life.

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INTRODUCTION

In the last decade almost all of cultural heritage institutions use digital resources. In addition to the exact digital copies of their artifacts and speciments, cultural heritage institutions hold various types and formats of multimedia content that is used for educational purposes in the scope of the cultural heritage that is preserved in those spaces, such as simple text or hypertext, audios, videos, games and quizzes for children and adults, 2D and 3D visualisations, and even simulations. These digital resources form a rich source of knowledge about cultural heritage, natural history, and biodiversity that could be used to serve various educational contexts and scenarios, not only to support learning "about cultural heritage" that is preserved in those institutions, but also "learning from cultural heritage" out of the scope of these institutions.

However, due to a number of barriers, an impressive abundance of multimedia content available remains largely unexploited. One one hand digital resources in some institutions are still accessed in a limited way and utilized through rather static modes of delivery. On the other hand, there is a lack of efficient support on top of existing digital libraries implementations for learning applications. One of the main challenges for a multimedia library is to provide effective access to its content and personalize the user's experience to fit his/her current goals and interests in the best possible way. From a Learner user perspective this would mean accessing this information in a way that best fits to his/her learning needs and preferences, including cognitive preferences as learning style. From a teacher or (museum) educator user perspective this would mean to be able to access, use and "transform" this content to develop meaningful and effective learning experiences for different educational contexts and needs. These scenarios however are not efficiently supported on top of multimedia digital libraries.

The goal of this thesis is to provide a comprehensive approach for taking advantage of existing cultural digital materials residing in cultural heritage institutions to support the creation and provision of effective pedagogy-driven learning experiences not only in the context of cultural heritage preserved in these institutions, but also to serve other learning contexts and scenarios. Towards this end, the thesis has the following objectives described from a stakeholders'/users' point of view: a) support the needs of institutions preserving cultural heritage through opening their cultural collections to the learning community and their visitors and supporting effectively formal and informal learning applications on top of them, b) support the educators and teachers accessing cultural digital content residing in those institutions collections and developing learning experiences to effectively support the needs of different learners in a pedagogically-sound way maximizing the learning outcome, and c) support Learners with different needs and preferences accessing cultural material in an effective pedagogy-driven personalized way.

The PhD thesis includes introduction, 6 chapters, conclusion, contributions and future directions of the thesis, literature, a list of 13 publications of the author associated with the submitted dissertation, and a list of their citations.

Chapter 1 "Motivation, goal, objectives and taks of the PhD thesis" presents the motivation of this thesis, e.g. the problem of supporting effective personalized learning experiences on top of multimedia digital libraries taking advantage of existing cultural digital materials residing in cultural heritage institutions. The goal, objectives and tasks of the thesis are also presented.

Chapter 2 "Study of the problem" aim is studying this problem: a) Study the concepts and components of digital libraries and digital objects, as well as eLearning systems and learning objects; b) Study main interoperability standards, specifications and approaches for the description, packaging and access of (cultural) digital objects and learning objects, and for repositories interoperability; c) Study personalization in Digital Libraries and learning: approaches for personalization in DL, user modeling and profiling; the characteristics of the Learner as a user and how they (should) affect personalization; instructional design and personalization; approaches for adaptive personalization in eLearning; and finally d) Analyze in detail the problem(s) that this thesis has to address, present the envisioned scenario and compare it with current solutions.

Chapter 3 "Modeling the environment to support pedagogy-driven personalization" presents the modeling of the environment to support the construction and provision of pedagogy-driven personalized learning experiences. In specific, the following models are defined: 1) the Domain model: Description and structuring of the object layers to support pedagogy-driven personalization; Authoring/repurposing process and pedagogical aspects and requirements for the proper description and structuring of the object layers to support pedagogy-driven personalization, 2) the Learner model taking into account the learner needs and preferences identified as important factors to personalization, 3) the Instructional model for the encoding of instructional strategies (abstract training scenarios), and 4) the Adaptation model as an algorithm for the dynamic construction of pedagogy-driven personalized learning experience taking into account the current learner needs and preferences.

Chapter 4 "Architecture" presents an integrated service-oriented architecture and its functional components based on the modeling presented in Chapter 3 to support access, use and re-purposing of the cultural digital content residing in cultural heritage institutions for the development of learning experiences to support different learning needs and contexts. Integral part of this architecture are components to support the development of pedagogically-driven personalized learning experiences statically or dynamically, as they have been modeled and described in the previous chapter. The

architecture exploits widely-accepted standards and protocols and supports interoperability with existing eLearning systems and large repositories/aggregators.

Chapter 5 "Implementation and application of the proposed framework and architecture" presents the implementation of the proposed framework and architecture in LOGOS project, and its application in the implementation of Natural Europe project.

Chapter 6 "Experimentation and evaluation" presents the experimentation and evaluation of the proposed framework performed in the context of LOGOS project.

The results and directions for further development and deepening of the study are presented in "Contributions of the thesis".

Major scientific and applied contributions of the thesis are:

- Developed a framework and models for supporting effective personalized learning services on top of multimedia digital libraries, by a) supporting re-purposing of multimedia digital content/archives to cultural digital objects, learning objects and higher learning units, b) supporting the construction of pedagogy-driven personalized learning experiences on top of multimedia digital archives statically or dynamically. Towards this end defined 4 models: domain model, learner model, instructional model and adaptation model.

- Developed an integrated service-oriented architecture and functional components (including repositories, tools, delivery components, applications and services) based on interoperability-standards to support repurposing of existing multimedia digital content to cultural digital objects, learning objects and higher learning units for the construction of pedagogy-driven personalized learning experiences statically or dynamically. The architecture supports interoperability and sharing of cultural digital objects, learning objects and learning experiences with existing eLearning systems and large repositories/aggregators.

- Implementation of the proposed framework and architecture in LOGOS project and application of the proposed methodology and solutions in the implementation of Natural Europe project to support the need of Natural History Museums to make available their cultural digital collections and support their gradual repurposing to develop pedagogy-driven learning experiences with the use of educational pathways based on educational templates.

The main text of the thesis is accompanied by six appendixes.

Results from the research done in a number of **European Research & Development projects** (listed below) were combined, enriched, specialized and applied in the PhD thesis for the domain of cultural digital libraries:

- Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018), funded by the Bulgarian Sciences Fund,
- IST/STREP LOGOS project "Knowledge-on-Demand for Ubiquitous Learning" (IST-4-027451),
- ICT/PSP Natural Europe project "Natural History & Environmental Cultural Heritage in European Digital Libraries for Education" (FP7-ICT-PSP: 250579),
- LdV/ToI QONIAon project "VET Qualification Practice for e-Inclusion" (2013-1-TRI-LEO05-47585), and
- ICT/PSP Open Discovery Space project "A socially-powered and multilingual open learning infrastructure to boost the adoption of eLearning resources" (FP7-ICT-PSP: 297229).

Furthermore, parts of the work done in the scope of this thesis have been published in a number of **peer reviewed journals and conference proceedings** (see "LIST OF THE AUTHOR'S PUBLICATIONS RELATED WITH PHD THESIS"): International Journal on Digital Libraries - IJDL (Springer, 2014) and International Journal of Education and Information Technologies (NAUN, 2016), 6th International Conference on Web-based Learning - ICWL 2007 (Edinburgh, UK, 2007), IEEE International Conference on Advanced Learning Technologies - ICALT 2007 (Niigata, Japan, 2007), Workshop on Cross-Media and Personalized Learning Applications on top of Digital Libraries (LADL2007) in conj. with ECDL2007 Conference (Budapest, Hungary, 2007), 2nd LOGOS Open Workshop on "Cross-Media and Personalized Learning Applications with Intelligent Content" (LAIC 2008) in conj. with AIMSA2008 Conference (Varna, Bulgaria, 2008), Metadata Semantics and Research Conference - MTSR2011 (Izmir, Turkey, 2011) and MTSR2013 (Thessaloniki, Greece, 2013), 2nd International Conference on E-Learning, and E-Technologies in Education - ICEEE 2013 (Lodz, Poland, 2013), 17th International Conference on Theory and Practice of Digital Libraries - TPDL2013 (Valetta, Malta, 2013), IEEE Interactive Mobile Communication Technologies and Learning - IMCL2014 (Thessaloniki, Greece, 2014), and International Conference on e-Learning - eLearning'16 (Bratislava, Slovakia, 2016). About 40 citations have been detected.

The work presented in this thesis can be extended or further developed in the following directions:

- Theoretical direction: 1) Extension/adaptation of the developed models towards supporting re-purposing and transformation of a digital library content, and provision of personalized experiences in other domains and applications (at the same time), such as eScience, eResearch etc. This extension is possible since the proposed framework is generic enough to support multiple-context views of the content of a digital library and its transformation targeting at different applications. 2) Extension and exploitation of the framework to support the construction of Personal Learning Environments (PLEs), combining tools, services and resources, which learners use to direct their own learning and pursue educational goals.

- Applied/practical direction: Implementation and experimentation with other applications (eScience, eResearch etc.) on top of digital libraries, i.e. to offer services and tools supporting re-purposing of the underlying content, and provision of effective personalized experiences by real-time integration of content, tools and services to fit the needs of different target groups.

Chapter 1. MOTIVATION, GOAL, OBJECTIVES AND TAKS OF THE PHD THESIS

1.1. Motivation

Libraries have been always being an important source of knowledge. The technology evolution transformed the traditional 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 multimedia digital library, the managed content is not restricted to the usually mainly textual documents, but it also contains media types like music, videos, images, maps, and mixtures of different content types (multimedia objects) for different uses. 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 content (based on adequate indexing) and to provide support for the "real-time" integration of different content types. [Neuhold and Niederée, 2003]

Some challenges of multimedia libraries are closely related to those of cultural heritage institutions, e.g. Galleries, Libraries, Archives, and Museums (or GLAM) that (want to) make multimedia representations of their artifacts available online [Neuhold and Niederée, 2003]. The main goal of these institutions is the digitization of tangible or intangible heritage and consequently its collection and preservation. But in addition they aim to reinforce the accessibility to large public, stakeholders' engagement and sensitization [Glushkova et al., 2015]. Cultural heritage institutions re-think their role and explore new possibilities to serve different social needs and applications, such as learning.

In the last decade almost all of them use digital resources. In addition to the exact digital copies of their artifacts and speciments, cultural heritage institutions hold various types and formats of multimedia content that is used for educational purposes in the scope of the cultural heritage that is preserved in those spaces, such as simple text or hypertext, audios, videos, games and quizzes for children and adults, 2D and 3D visualisations, and even simulations. These digital resources form a rich source of knowledge about cultural heritage, natural history, and biodiversity that could be used to serve various educational contexts and scenarios, not only to support learning "about cultural heritage" that is preserved in those institutions, but also "learning from cultural heritage" out of the scope of these institutions.

However, due to a number of barriers, an impressive abundance of multimedia content available remains largely unexploited. One one hand digital resources in some institutions are still accessed in a limited way and utilized through rather static modes of delivery. On the other hand, there is a lack of efficient support on top of existing digital libraries

implementations for learning applications. 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. Digital libraries are domain and institutionally specific, they are heterogeneous in scope and yield different functionality, while digital contents have been organized and described differently, using different standards and specifications or non standard schemes, and from different context views targeting to different users and applications and not (necessarily) learning. Moreover, a digital library should provide effective access to its content and personalize the user's experience to fit his/her current goals and interests in the best possible way. From a Learner user perspective this would mean accessing this information in a way that best fits to his/her learning needs and preferences, including cognitive preferences as learning style. From a teacher or (museum) educator user perspective this would mean to be able to access, use and "transform" this content to develop meaningful and effective learning experiences for different educational contexts and needs. These scenarios however are not efficiently supported on top of Digital Libraries.

1.2. Goal, objectives and tasks of the thesis

The goal of this thesis is to provide a comprehensive approach for taking advantage of existing cultural digital materials residing in cultural heritage institutions to support the creation and provision of effective pedagogy-driven learning experiences not only in the context of cultural heritage preserved in these institutions, but also to serve other learning contexts and scenarios. Towards this end, the thesis has the following objectives described from a stakeholders'/users' point of view:

- support the needs of institutions preserving cultural heritage through opening their cultural collections to the learning community and their visitors and supporting effectively formal and informal learning applications on top of them,
- support the educators and teachers accessing cultural digital content residing in those institutions collections and developing learning experiences to effectively support the needs of different learners in a pedagogically-sound way maximizing the learning outcome, and
- support Learners with different needs and preferences accessing cultural material in an effective pedagogy-driven personalized way.

The goal and objectives of the thesis will be realized through the following tasks:

Task 1: Study of the problem

This task is realized through the following steps:

- Study the concepts and components of digital libraries and digital objects, as well as eLearning systems and learning objects.
- Study main interoperability standards, specifications and approaches for the description, packaging and access of (cultural) digital objects and learning objects, and for repositories interoperability.
- Study personalization in Digital Libraries and learning: approaches for personalization in DL, user modeling and profiling; the characteristics of the Learner as a user and how they (should) affect personalization; instructional design and personalization; approaches for adaptive personalization in eLearning.
- Analyze in detail the problem(s) that this thesis has to address, present the envisioned scenario and compare it with current solutions.

Task 2: Modeling the environment to support pedagogy-driven personalization.

This task is realized through the following steps:

- Define the domain model; Description and structuring of the object layers to support pedagogy-driven personalization.
- Define the learner model taking into account the learner needs and preferences identified as important factors to personalization.
- Define the instructional model for the encoding of instructional strategies (abstract training scenarios).
- Define the adaptation model for the dynamic construction of pedagogy-driven personalized learning experience taking into account the current learner needs and preferences.

Task 3: Present the architecture to address the identified problems and meet the user requirements set, and the functionality and services of its components.

Task 4: Implementation and application of the proposed framework and architecture.

Task 5: Experimentation and evaluation of the proposed framework/architecture.

Developed services and tools will comply with the recommendations and requirements of established global standards and protocols in the field of digital libraries and eLearning to ensure interoperability with other implementations as much as possible, and flexibility, variability, extensibility and sustainability.

Chapter 2. STUDY OF THE PROBLEM

2.1. Introduction

Supporting pedagogy-driven personalized learning experiences on top of multimedia digital libraries is a complex problem with two poles and many dimensions. The aim of this chapter is to study this problem, and in specific:

- Study the concepts and components of digital libraries and digital objects, as well as eLearning systems and learning objects.
- Study main interoperability standards, specifications and approaches for the description, packaging and access of (cultural) digital objects and learning objects, and for repositories interoperability.
- Study personalization in Digital Libraries and learning: approaches for personalization in DL, user modeling and profiling; the characteristics of the Learner as a user and how they (should) affect personalization; instructional design and personalization; approaches for adaptive personalization in eLearning.
- Analyze in detail the problem(s) that this thesis has to address, present the envisioned scenario and compare it with current solutions.

2.2. 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.

A Digital Library mediates between the information needs of its user community and the globally available content. This is achieved by contributions in four areas [Niederée, Steffens, Hemmje, 2002]:

- Content pre-selection: The library selects high-quality content potentially relevant for the members of its user community;
- Content structuring: The library structures the content according to the predominant domain understanding of its user community;
- Content enrichment: Domain and library experts as well as community members enrich content objects with descriptive and value-adding metadata;
- Library services: Services for content retrieval, access, annotation, etc. support the identification of relevant material and facilitate content access;

Best practices and significant results in the field of digital libraries in the last decade have led to the creation of a reference model for digital libraries (Digital Library Reference Model, DLRM) [Candela et al., 2007] from several European research groups of the DELOS Network of Excellence on Digital Libraries for the basic concepts, structures and activities in digital libraries. The reference model for digital libraries identified six key areas that are expected to cover the design of any digital library: content, architecture, users, functionality, quality and policies. The model identifies three different types of systems operating in the Digital Library universe [Candela et al., 2008]:

- Digital Library (Digital Library) - organization, including virtual, which collects, manages and preserves the long term rich digital content and offers different types of users specialized functionality to access such content in accordance with well-defined quality criteria explicit policies;
- The software system of digital library (Digital Library System) - a software system based on a specific architecture that provides functionality required by a specific digital library. End users "communicate" with digital library using this system;
- The management system for digital library (Digital Library Management System) - a software platform that provides the necessary infrastructure for the construction and administration of the software system of digital library and opportunities to integrate additional software, allowing expansion and enrichment of supported functionality.

According to this reference model there are three types of end-users characterizing the the operation of the Digital Library service: (i) Content Creators – the “producers” of

the DL Content; (ii) Content Consumers – the "clients" of the DL Content; and (iii) Digital Librarians – the "curators" of the DL Content.

In this thesis, the following definitions will be used [Sotirova et al., 2012]:

- A **Repository** consists of digital objects, organized in collections sets, which are stored and managed in computer networks and described with metadata.

- A **Digital Library** is a fully packed repository, with relevant user interface and services to support the needs of different communities. Digital library is domain and institutionally specific;

- An **Aggregator** is a repository, which ingests and manages digital content from different sources into a repository. It does not obligatory have user oriented interface; does not provide services; is not obligatory a heritage holder. Aggregator could be only a technical mediator between the holder institution and its digital library. The process of data ingesting/management follows technical and technological requirements of a specific project.

2.2.1. Digital Objects

The basic elements in these structures are digital objects. In the broad sense, a digital object is an information object that has a digital form (at least one) and is described with metadata. Digital objects may be audio-visual objects, e.g. images, text, web pages, sound, animation, etc., which are usually grouped into collections to certain criteria and are stored in special storage facilities together with their meta-descriptions. These, according to the Library of Congress [METS, 2005], 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 (context(s) of use) [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 and contextualize them 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 (learning (digital) objects) and CIDOC CRM [CIDOC CRM, 2006] is widely used to describe digital objects from a cultural point of view (cultural (digital) objects).

2.3. eLearning systems

Information and Communication Technologies opened new horizons and opportunities in learning and teaching, overcoming problems and limitations of traditional approaches. 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 learning services anytime, anywhere. For the development of such systems 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.

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

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.

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.

2.3.1. Learning Objects

In eLearning environments the material is cut into smaller independent pieces 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 at any place 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]. 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 according. As with LEGO bricks the idea is to build small, self-contained, reusable components that can be aggregated with other components [Hodgins, 2002]. LOs should comply with cohesion (each unit should do one thing and only one thing) and minimized coupling (the unit (software module/learning object) should have minimal bindings to other units)

[Boyle, 2003]. There is a common consensus that a learning object should be should be **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) and **Durable** (to remain intact across upgrades of hard/software) [Rehak and Mason, 2003].

An important aspect for reusability and personalization is the granularity of learning objects. However the structure and composite nature of a learning object is still open to interpretation [Metros, 2005; Knight, Gašević, and Richards, 2005]. Confusion still exists 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? 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]. The Learnativity Content Model [Wagner, 2002], defining a global component architecture for LOs is one of them. This conceptual model described in the following section is adopted in this thesis.

2.3.2. The Learnativity model

The Learnativity Content Model [Wagner, 2002] illustrates the concept of assembling content into higher-level objects (Figure 2.1). Learning objects are assembled from information objects and assets 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. Reuse not only saves time and money, but also enhances the quality of digital learning experiences, resulting in efficient, economic and effective learning.

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

- **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.

- **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 phase 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).

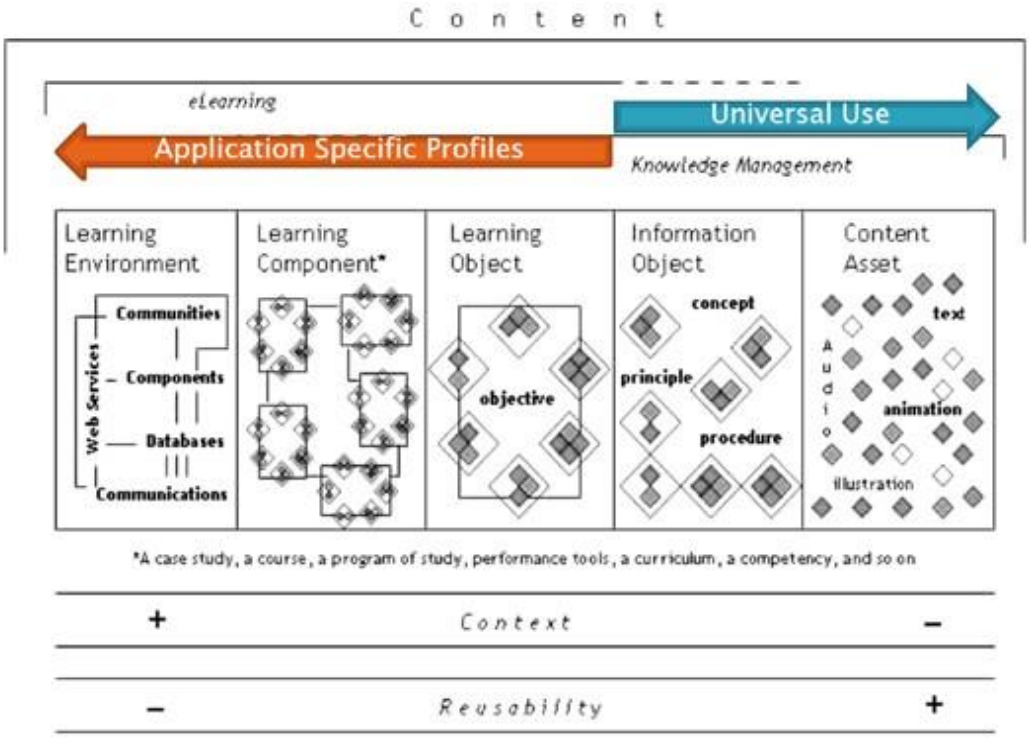

Figure 2.1 The Learnativity content model [Wagner, 2002]

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 2.1.

Digital resources reside at the first two levels (content assets and information objects), depending on how these are described and provided. Digital content described with primitive (legacy) metadata or no metadata fall in the first category (content assets), while semantically annotated objects stored in digital libraries/repositories fall in the second category (information objects). For the purposes of this thesis and in the context of

cultural heritage we will use the term Cultural Digital Objects to refer to objects at the level of information objects.

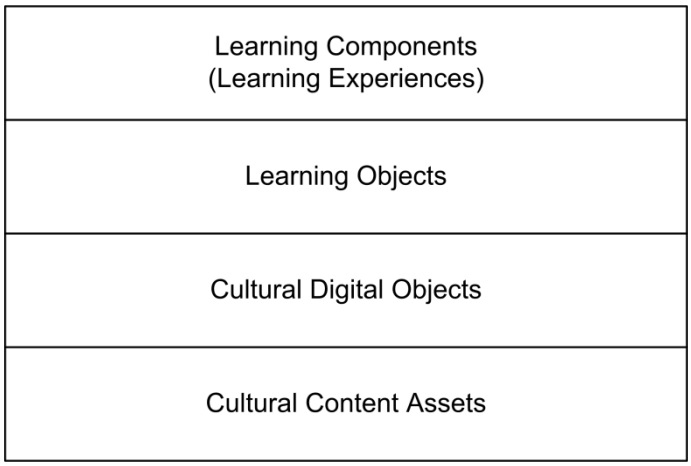

Figure 2.2 Stack of objects based on Learnativity model

We will also use the term Learning Experience residing at the level of Learning Components to refer to structured learning activities with specific objectives that may be supported by Learning Objects (or/and services) which a Learner experiences to accomplish a target learning goal.

2.4. Standards, specifications and approaches for interoperability of (cultural) digital objects

Consistent structure and content of metadata across a digital object collection enables the material to be sorted, searched and browsed effectively. Consistency across a metadata set reduces duplication of effort, especially when indexes, thesauri and authority control are used. It also enables interoperability between datasets and the possibility of harvesting and aggregating resources from different sources. The structure and content of metadata is best dictated by recognized standards. These are developed and maintained by particular user communities, through formal consensual development processes, to enable the best possible intellectual control of different resource types. [Foster and Rafferty, 2016]

Conceptual linkage between the constituent parts of complex digital objects can be achieved through the use of packaging standards [Foster and Rafferty, 2016]. These also support the logical binding together of digital objects and their metadata.

2.4.1. Standards for description and packaging of (cultural) digital objects

Reports in the context of ATHENA [McKenna and De Loof, 2009], MINERVA [Fernie, Francesco, and Dawson, 2008] and PrestPRIME [Schreiber, 2010] projects and [Sotirova et al., 2012] provide extensive surveys on standards and specifications for the description of (cultural) digital objects.

The most widely used standard for the discovery and interpretation of digital objects is Dublin Core (DC) [DC, 1999], a simple descriptive metadata schema developed by a cross-disciplinary initiative and designed to support the discovery of resources from across a range of domains. The more recent Europeana Semantic Elements specification (ESE) [ESE, 2013] is a Dublin Core-based application profile used in the Europeana.eu. It provides a generic set of terms that can be applied to heterogeneous materials providing a baseline to allow contributors to take advantage of their existing rich descriptions.

In addition, ontologies, taxonomies and vocabularies are usually used for the semantic description of digital objects. In order for a semantic annotation process to be effective in terms of exploitation (i.e. others can understand the annotations), a community wide accepted ontology or vocabulary has to be defined and agreed among the various stakeholders.

The MPEG7, formally named "Multimedia Content Description Interface", is an ISO/IEC standard offering 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.

For the packaging of digital objects the Metadata Encoding Transmission Standard (METS) developed by the library and archive domain is widely used. The standard has been impemented in a large selection of software products providing support for it [Repositories Support Project, 2010]. Other standards have been used to package digital objects, most notably the Multimedia Application Metadata (MPEG21), which has its origins in the multimedia industry, but implementations have been experimental [Bekaert, Hochstenbach and Sompel, 2003; Foster and Rafferty, 2016]

In the following sections we focus on standards and specifications that are related with and are in the scope of this thesis.

2.4.1.1. Dublin Core (DC)

Dublin Core (DC) [DC, 1999] defines fifteen elements to support simple cross-domain resource discovery: Title, Creator, Subject, Description, Publisher, Contributor, Date, Type, Format, Identifier, Source, Language, Relation, Coverage and Rights. Its use has been mandated by several governments in Europe (e.g. UK) and throughout the world (e.g. Australia).

According to the guidelines of MINERVA project for digital cultural content creation [Fernie, Francesco, and Dawson, 2008], to support the discovery of their resources by a wide range of other applications and services, projects must capture and store sufficient descriptive metadata to be able to generate a metadata description for each item using the Dublin Core Metadata Element Set (DCMES) in its simple/unqualified form. To support discovery within the cultural heritage sector, projects should also consider providing a metadata description for each item conforming to the DC.Culture schema.

But how can the a/v characteristics of content be described with DCMI Metadata Terms? Two terms which could be used for structuring objects are hasPart and isPartOf. But terms for further description of substructures (e.g. a time code) are not available.

2.4.1.2. Europeana Semantic Elements (ESE) and Europeana Data Model (EDM)

The Europeana Semantic Elements specification [ESE, 2013] defines the set of metadata elements used in the Europeana.eu. To provide metadata in the ESE format, it is necessary for contributors to map elements from their own metadata format to ESE. In addition to the mapping it is necessary for a normalisation process to be carried out on some values to enable machine readability. To this end, an XML Schema has also been produced (building on DC and DCTERMS schemes) as a further tool to assist providers in ensuring compliance with ESE. The ESE specification defines an extensive list of elements. However, it classifies them according to their importance in achieving a common basis for answering "who, what, where and when" questions.

Strongly recommended	Recommended	Additional elements	Europeana elements
dc:title	dc:coverage	dc:format	europeana:country
dcterms:alternative	dcterms:spatial	dcterms:extent	europeana:dataProvider
dc:creator	dcterms:temporal	dcterms:medium	europeana:hasObject
dc:contributor	dc:description	dc:identifier	europeana:isShownAt
dc:date	dcterms:isPartOf	dc:rights	europeana:isShownBy
dcterms:created	dc:language	dcterms:provenance	europeana:language
dcterms:issued	dc:publisher	dc:relation	europeana:object
	dc:source	dcterms:conformsTo	europeana:provider
	dc:subject	dcterms:hasFormat	europeana:rights[7]
	dc:type[7]	dcterms:isFormatOf	europeana:type[7]
		dcterms:hasVersion	europeana:unstored
		dcterms:isVersionOf	europeana:uri
		dcterms:hasPart	europeana:usertag
		dcterms:isReferencedBy	europeana:year
		dcterms:references	
		dcterms:isReplacedBy	
		dcterms:replaces	
		dcterms:isRequiredBy	
		dcterms:requires	
		dcterms:tableOfContents	

Figure 2.3 ESE specification elements [ESE, 2013]

Figure 2.3 illustrates the specification's elements according to their classification as presented in the "Metadata Mapping & Normalisation Guidelines for the Europeana Semantic Elements" document delivered by Europeana.eu.

The Europeana Data Model (EDM) [EDM, 2011] is a new proposal for structuring the data that Europeana will be ingesting, managing and publishing. The Europeana Data Model is a major improvement on the Europeana Semantic Elements (ESE), the basic data model that Europeana began life with. Each of the different heritage sectors represented in Europeana uses different data standards, and ESE reduced these to the lowest common denominator. EDM reverses this reductive approach and is an attempt to transcend the respective information perspectives of the sectors that are represented in Europeana – the museums, archives, audiovisual collections and libraries.

2.4.1.3. Multimedia Content Description Interface (MPEG7)

MPEG-7 defines a set of description tools, called description schemes (DS) and descriptors (D). Descriptors represent single properties of the content description, while description schemes are containers for descriptors and other description schemes. The definition of description schemes and descriptors uses the Description Definition Language (DDL), which is an extension of XML Schema. [Schreiber, 2010]

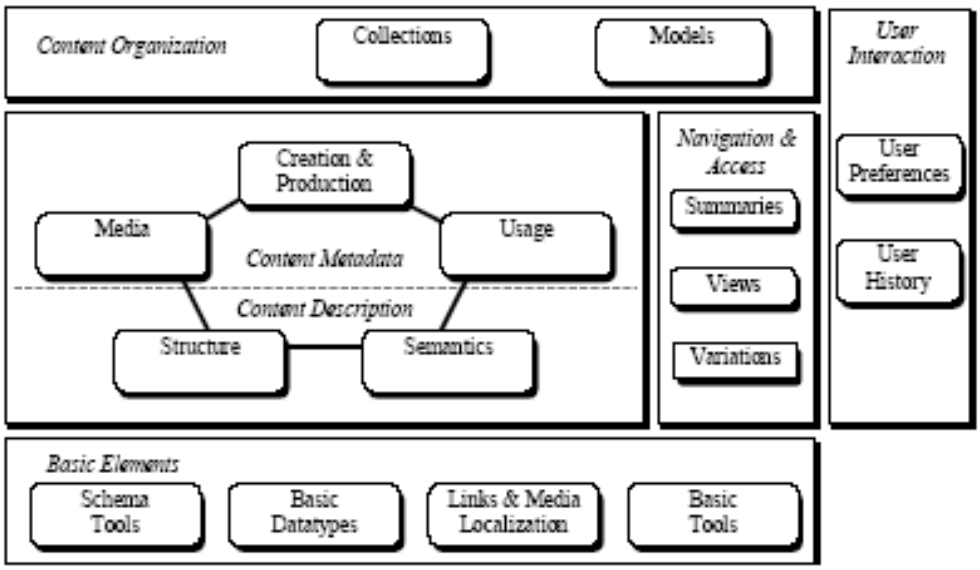

Figure 2.4 Overview of the Multimedia Description Scheme (MDS) description tools [MPEG7, 2001e]

An important part of MPEG-7 are the Multimedia Description Schemes (MDS) [MPEG7, 2001e], which provide support for the description of media information, creation and production information, content structure, usage of content, semantics, navigation and access, content organisation and user interaction (Figure 2.4) [Schreiber, 2010]. The structuring tools are very flexible and allow the description of content on different levels of granularity. In addition, the Audio and Visual parts define low- and

mid-level descriptors for these modalities. MPEG7 Visual includes the Description Tools describing (only) Visual descriptions covering the basic visual features: Color, Texture, Shape, Motion, Localization and Face Recognition [MPEG7, 2001c]. MPEG7 Audio provides the Description Tools dealing with (only) Audio descriptions and in conjunction with the MDS part of the standard provides structures for describing audio content [MPEG7, 2001d].

2.4.1.4. 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. 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, administrative and structural metadata.

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.

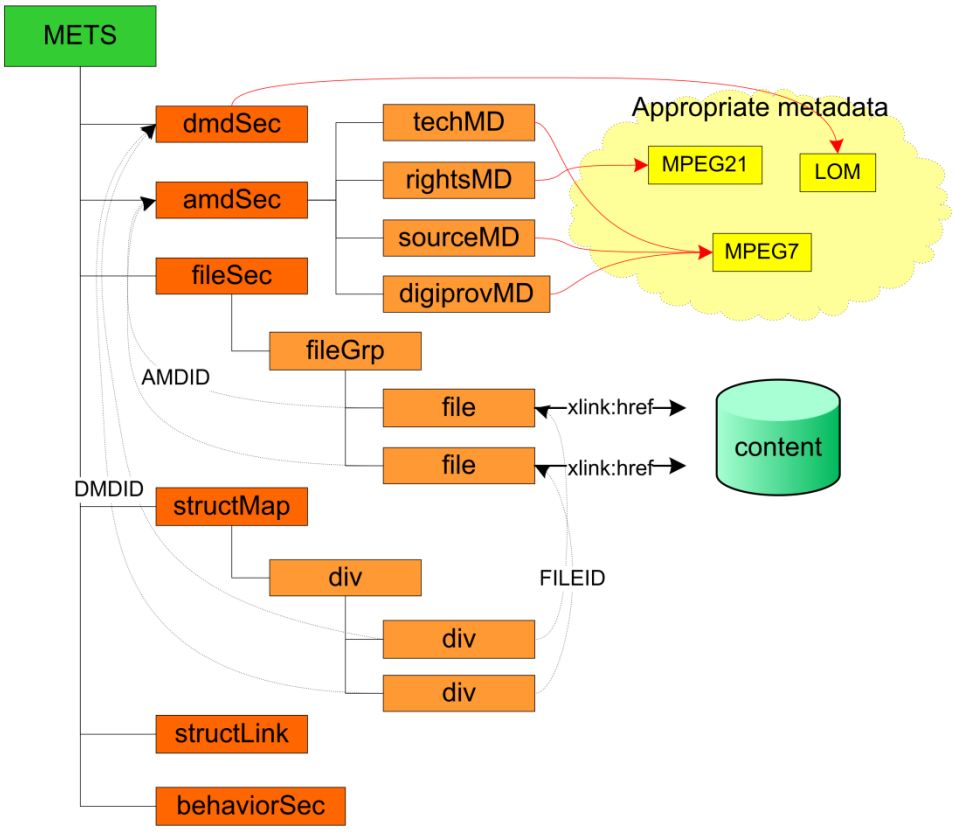

Figure 2.5 The typical structure of a METS document. Any preferred metadata scheme can be used for the descriptive and administrative metadata of the current digital object (e.g. LOM, MPEG7, MPEG21)

The framework proposed in this thesis makes use of METS to support an hierarchical approach in the categorization of the objects it manages (cultural digital objects, learning objects, and learning components) and their representation and also support multiple-(educational) contexts views of digital objects.

2.4.2. Related work on accessing cultural digital material

Important projects have been launched to propose digital platforms and provide access to cultural digital material [Glushkova et al., 2015], such as Athena (Athena, 2011), ECHO - European Cultural Heritage Online Initiative (Echo-Cultural Heritage Online, 2014), CAN (Collections Australia Network, 2011), and some private projects such as the Google Art Project (Google Art Project, 2013). These web portals provide access to paintings, music, museum objects, archives that have been digitized with the use of new technologies. One of the most important EU-funded project is Europeana (Europeana.eu, 2009), which is the most well-known portal for exploring the digital resources of Europe's museums, libraries, archives and audiovisual collections, thus offering direct access to millions of books, manuscripts, paintings, films, museum objects and archival records that have been digitised throughout Europe. From an architectural point of view, Europeana.eu constitutes a search engine and a database. It contains metadata integrated by providers and uses that database to allow users to search for cultural heritage objects, and to find links to those objects (Dekkers, 2011). To browse and search the objects and their links, different methods are used such as a timeline, a map Search, an openSearch API. The data is also made available as Linked Open Data, it is represented in the European Data Model (EDM) and the described resources are addressable and dereferencable by their URIs (Halshofer, Isaac 2011). [Glushkova et al., 2015]

2.5. Standards for description and packaging of learning objects and higher learning units

2.5.1. 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). Data elements describe a learning object and are grouped into categories. The LOMv1.0 Base Schema consists of nine such categories (Figure 2.6):

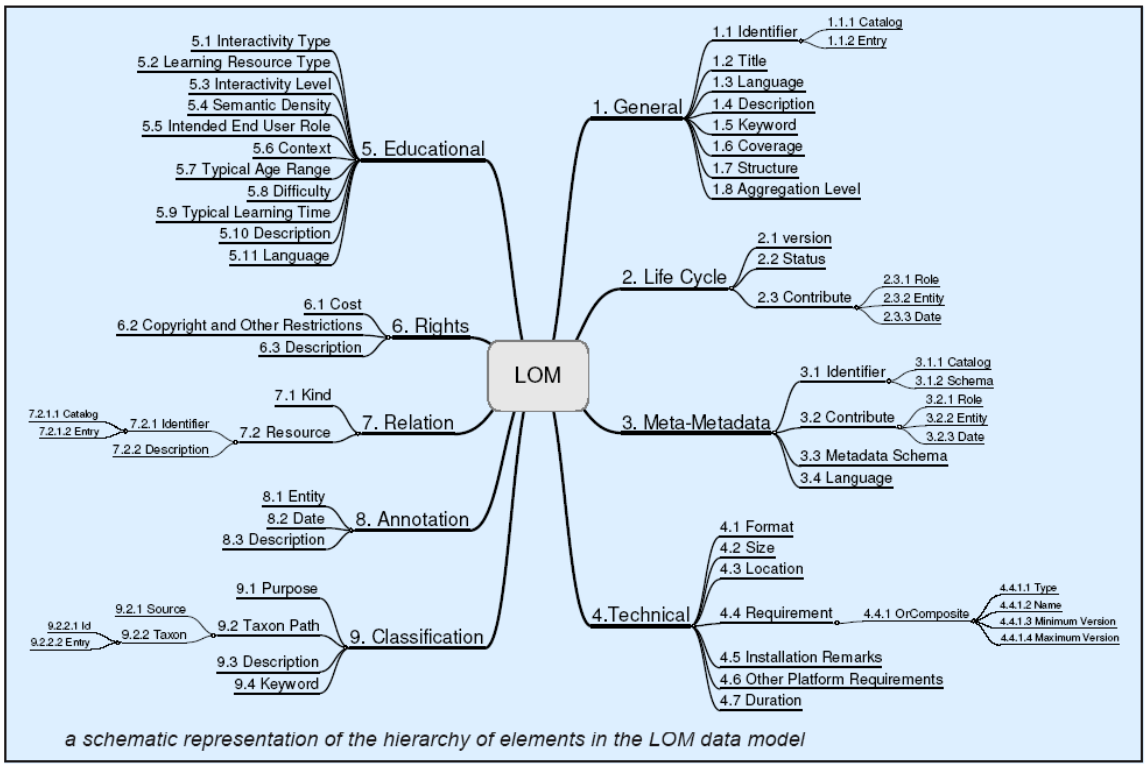

Figure 2.6 A schematic representation of the hierarchy of elements in the LOM data model [Barker, 2005]

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

2.5.2. IMS Question & Test Interoperability specification

The IMS Question & Test Interoperability specification [IMS QTI, 2005] 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 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 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).

IMS QTI is used in this framework for the representation of assessment tests and items that are used to assess the satisfaction of certain learning objectives. Assessment tests and items are described with LOM metadata.

2.5.3. Sharable Content Object Reference Model (SCORM)

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.

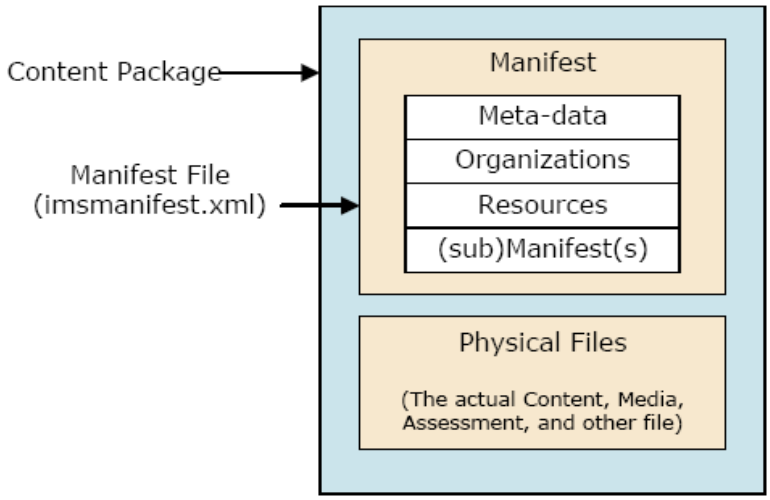

Figure 2.7 Content Package Components

To understand better the components of a SCORM Content Package the standard provides the conceptual diagram illustrated in Figure 2.7 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).

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 dissertation SCORM is used as the delivery means of final learning experiences to eLearning applications.

2.6. Standards for digital repositories interoperability

There are several standards for the interoperation of digital repositories, such as the IMS Digital Repository Interoperability (IMS DRI) [IMS DRI, 2003], the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) [OAI, 2008], the Edusource Communication Language [Hatala et al., 2004], the OAI-Object Reuse and Exchange [OAI-ORE, 2014] etc. In the following sections IMS DRI and OAI-PMH are presented, which have been adopted and implemented by major repositories and used in this theses.

2.6.1. 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.

IMS DRI defines five basic functions: search/expose, gather/expose, submit/store, request/deliver, and alert/expose. For the search function, the specification recommends using XQuery (www.w3c.org/XML/Query) with SOAP protocol or Z39.50. For the gather function, the OAI-PMH harvesting protocol is recommended. 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
- Intermediares: Services that reside between the above two (e.g. aggregators, brokers)

Aiming at very broad application of the specification the DRI document makes recommendations only to a certain level and leaves the resolution of more operational issues to the system implementers.

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

2.6.2. Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH)

The Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) [OAI, 2008] is a low-barrier mechanism for repository interoperability. It specifies a method for digital repositories ("data providers") to expose metadata about their objects for harvesting by aggregators ("service providers"), which may subsequently provide search and other services based on the aggregated collections of metadata. OAI-PMH is widely used to harvest (or collect) metadata descriptions of the records in a repository into a central point.

Data Providers are repositories that expose structured metadata via OAI-PMH. Service Providers then make OAI-PMH service requests to harvest that metadata. According to the OAI-PMH V2.0 specification [OAI, 2008], a target service has to implement the following verbs (i.e. methods) as services that are invoked within HTTP. Each verb corresponds to an OAI-PMH request:

- Identify: The identification of the underlying repository
- ListMetadataFormats: A list of supported metadata formats
- ListIdentifiers: A list of identifiers
- ListRecords: A list of metadata records
- GetRecord: A metadata record containing the description about an item

These verbs are requested in REST style. i.e., every verb is, together with parameters, encoded as a URL. Through this URL, a harvester application can retrieve metadata stored in the underlying repository, formatted in XML.

The framework presented in this thesis proposes the implementation of the OAI-PMH protocol on top of its objects' repositories to allow their dissemination to external repositories/federations/aggregators as suggested in IMS DRI specification for the implementation of the Gather/Expose function.

2.7. Personalization in Digital Libraries and learning

The DELOS/NSF Working Group on Personalisation and Recommender Systems for Digital Libraries defines personalisation as "the ways in which information and services can be tailored to match the unique and specific needs of an individual or a community. This is achieved by adapting presentation, content, and/or services based on a person's task, background, history, device, information needs, location, etc., essentially the user's context" [Callan et al., 2003].

According to the DELOS/NSF Working Group on Personalisation and Recommender Systems [Callan et al., 2003], "Personalization is required to make an increasingly heterogeneous population of digital libraries accessible to an increasingly heterogeneous population of users. It is no longer realistic to expect every user to adapt to every digital library. If a person must be an anthropologist to use an anthropological digital library, the library is available to only a limited community; if the library can tailor its services and materials for a wider range of users, the impact and utility of the library is magnified greatly. The next generation of digital libraries must support a wide range of personalized services that support the activities of a wide range of users".

Most often the personalization techniques in DLs includes the selection and recommendation of information resources, system interfaces and the means of navigation according to the personal characteristics of the user (demographic status, goals, tasks, skills, motivation, achievements, interests/disinterest, preferences, requirements, etc.) on one hand, and according to the user's behaviour in the environment on the other - a solution specified as personalization according to a user profile [Arapi et al., 2016].

Neuhold, Niederée, and Stewart (2003) distinguish personalization methods referring to library services and those referring to library content. In personalization of library services, they further distinguish services developed to support personalization, like individual notification and personal agents, and the personalization of service properties like e.g. personalized visualization or individual service configuration that also can be found in the personalization of other kinds of systems. The content personalization category, content selection, contains methods using information filtering based on user preferences and competences. An important application area is personalized information retrieval. The information about the user is used for query rewriting, for the filtering of query results as well as for a personalized ranking of query results. Further important application areas are decision support in content navigation and autonomous information agents. An alternative method for personalization in content selection are services that enable the active collection of relevant material e.g. in bookmark lists and other information containers.

In addition to the above methods, Neuhold, Niederée, and Stewart (2003) refer to the following "most-advanced" approaches: A) Personal Web Context taking into consideration the interrelationship of users with their neighborhood of entities in the domain. After discovering and representing the (existence and type of) relationships of the user with other entities of the domain this semantically annotated personal web of interrelationships is exploited in targeted personalization of a library's information offer. B) Personal Reference Libraries that follow the idea of personalized information spaces. They take into account the individual conceptualization of the information space that differs between users. Such reference libraries coexist and interact with other digital (reference) libraries in a controlled way balancing autonomy and cooperation. C) Cooperative Content Annotation taking into account the active role that a user of a digital library can play with respect to library content and metadata shifting him from a mere consumer to a contributor to library content and supports discourse and community building.

2.7.1. User modeling and profiling

User modeling can be defined as the process of acquiring knowledge about the user in order to provide services, adaptive and personalized information flow/s following its

specific requirements in the DL domain. Closely related to this solution are the personalization techniques adverting the ways of delivery and access the content, content adaptation and transformation, grouping, ordering, and reconstructing. [Arapi et al., 2016]

Main questions asked are [Arapi et al., 2016]:

- User interests: What is the user interested in? What needs to be done or accomplished?
- User preferences: How is something done or accomplished?
- User goals and intents: What the user actually wants to achieve?
- User motivation: What is the force that drives the user to be engaged in observation activities?
- User experience: What is the user's previous experience that may have an impact?
- User activities: What the user does in the DL environment, etc.

Building a user model for a DL involves defining: the "who", or the degree of specialization in defining who is modelled and what the user history is; the "what", or the cognitive goals, plans, attitudes, capabilities, knowledge, and beliefs of the user; the "how" the model is to be acquired and maintained; and the "why", including whether to elicit information from the user, give assistance, provide feedback, or interpret the user's behaviour. [Arapi et al., 2016]

The DL user model often covers a certain amount of information that can be divided into two main groups [Paneva, 2006]:

- General user information, such as actual and historic data (personal information), goals, interests, wishes, cognitive aptitudes, object observation style, measures for motivation state, preferences regarding the object presentation method, etc.,
- Information about user's behaviour in the library such as chosen paths for object observation, chosen objects and collections, overall competence level, difficulties during the understanding of the information, etc.

The DL user model can be formally presented by a user ontology, providing general concept framework, concept (class) relations, individuals, rules, axioms, facts, etc.

2.7.2. Understanding the Learner user

When the DL user is a learner, or has learning purposes in the environment, "one size fits all" solutions are not enough to satisfy his/her needs [Arapi et al., 2007]. Different DL users-learners have different learning needs and preferences that (should) affect the learning function outcome. Learners expect from the DL system a "personal facilitator" and not a "classroom" behaviour, where their personality and needs are known and taken into account. Based on Cronbach & Snow (1977), in learning personalization is most generally defined as an adaptation of the learning process and its content to the personal characteristics and preferences of the learner, as much as possible.

There are several benefits of thinking about and trying to understand learning preferences[1]:

- 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 learning 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 the selection of appropriate learning resources? Based on bibliography and related research, there are a number of factors that can influence the extent and outcome of learning such as the learning style, learner goals/objectives, previous knowledge, educational level and difficulty, technical and other preferences (e.g. language etc.). These factors and the way they should affect the learning plan and selection of content are analyzed in detail in the following sections.

2.7.2.1. Learning Style

In 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.

[1] http://www.sdc.uwo.ca/learning/index.html?styles

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 also been 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]. 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).

Here we should stress that the personalization framework presented in this dissertation 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.

2.7.2.1.1 Honey & Mumford's learning styles

Honey and Mumford have developed Kolb's ideas. Honey & Mumford's four key styles [Honey et al., 1992] 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

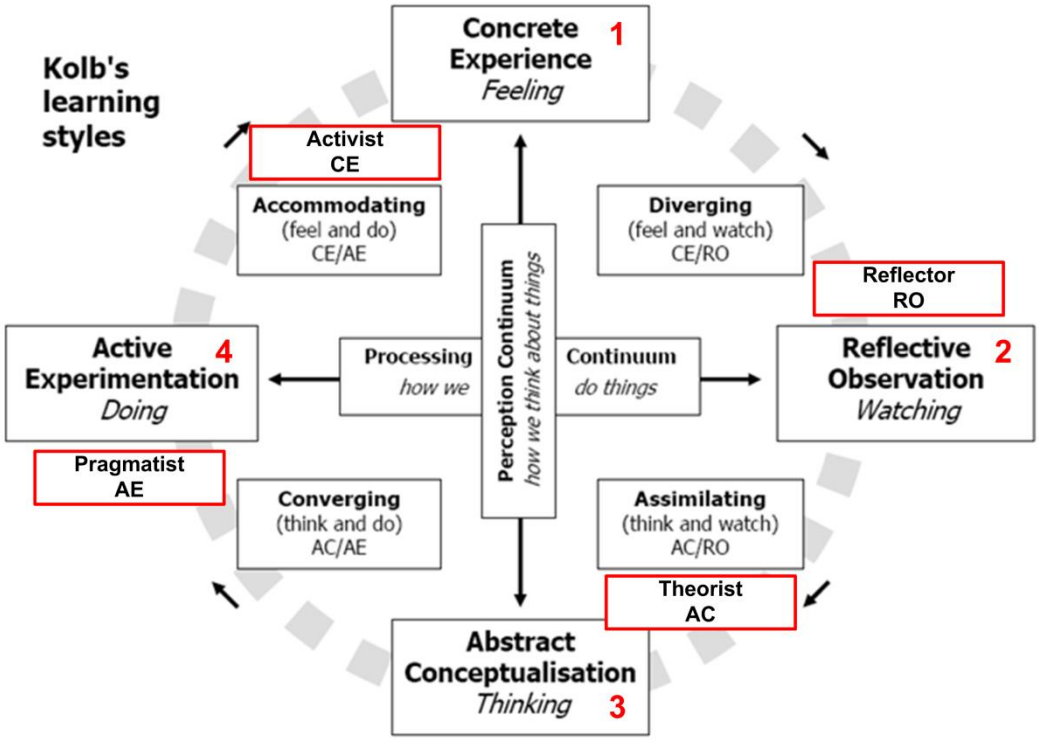

Figure 2.8 Honey & Mumford's learning styles and their relation to Kolb's learning styles (based on Alan Chapman 2005-6 adaptation and design figure)

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.

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.

2.7.2.2. 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].

Goals about what would be desirable to learn are central to making required decisions about what and how to learn. [Ram and Leake, 1995]. 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.

Table 2.1 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 meaning or structure.	categorize, combine, compile, compose, create, devise, design, explain, generate, modify, organize, plan, rearrange, reconstruct, relate, reorganize, revise, rewrite, summarize, tell, write
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

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 dissertation addresses this issue by providing a formal way for expressing Learning Objectives

exploiting Bloom's Taxonomy of educational objectives [Bloom and Krathwohl, 1965] (Table 2.1).

From the following diagram that shows the relationship between the Kolb's Experiental 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.

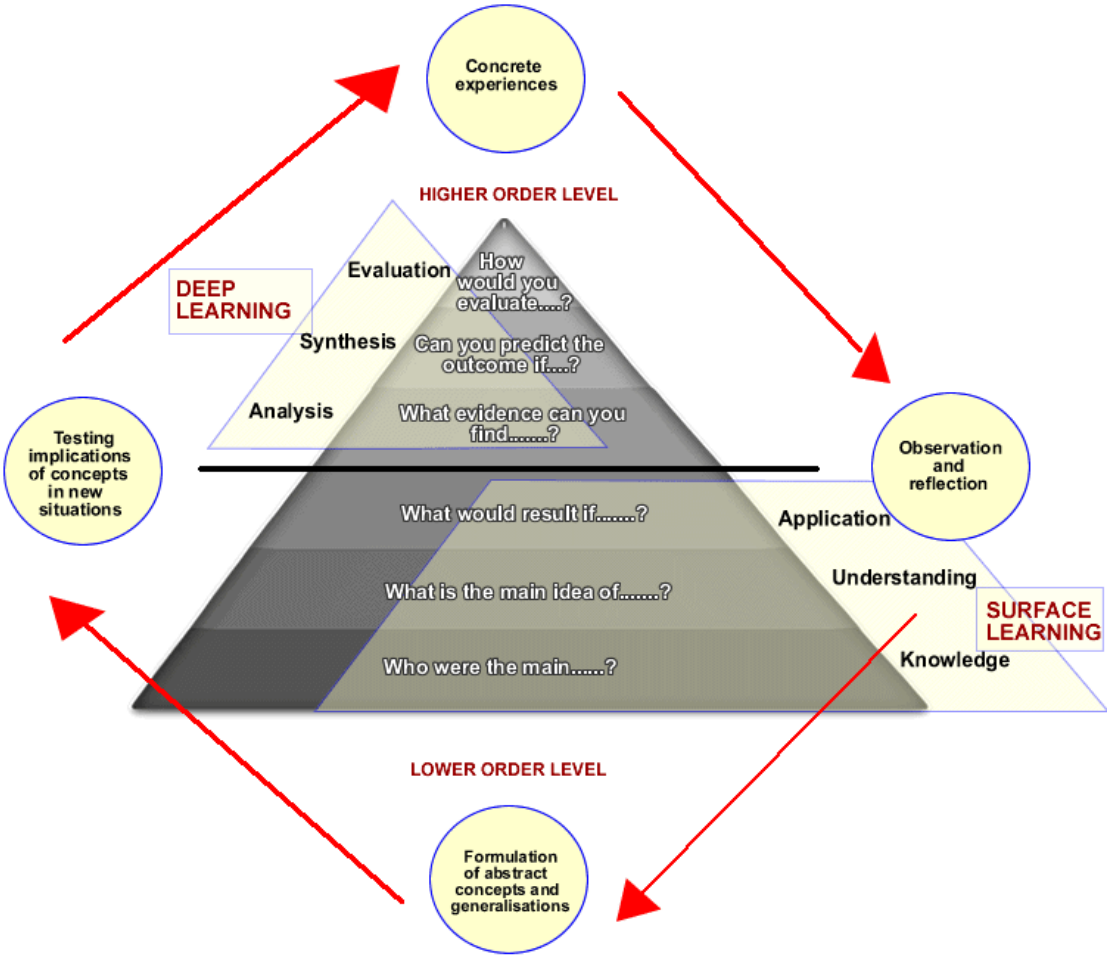

Figure 2.9 Relationship between Kolb's Experiental Learning Cycle and Bloom's taxonomy (retrieved from "The Business Case Study: A Suitable Candidate For Blended Learning?", http://www.cluteinstitute-onlinejournals.com/PDFs/200629.pdf)

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]. The framework presented in this thesis 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.

2.7.2.3. 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.

In order to be able for an instructor or an automated personalization process 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.

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 employed[2]:

2.7.2.4. 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] http://www.cmu.edu/teaching/designteach/teach/priorknowledge.html

2.7.2.5. Technical and other 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.

Other preferences may include 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. Language and learning provider preferences affect the selection of learning objects, while the preference regarding learning planner affects the selection of the learning plan.

2.7.3. Pedagogy-driven personalization

Personalization of the learners' learning experience was connected with the adaptation of the learning process and its content to the personal characteristics and preferences of the learner, as much as possible. We saw that different learners learn best in different ways, thus they 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. Towards this end taking into account pedagogy to support personalization is important.

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, syndissertation, 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.*

Moreover, *the instructional design process is usually performed completely by regular teachers lacking advanced pedagogical skills resulting in scenarios, where a sound pedagogical approach (the "how") is absent and the focus is mainly on "what" to teach (and finally not to learn...). As a matter of fact, these scenarios put the learners and their individual learning needs on the sidelines and this has a negative learning outcome*.

2.7.3.1. Pedagogical patterns/educational templates

If we could let instructional design experts to design the "missing part" (the "how"), this would help the teachers, educators and training professionals to design effective, efficient and appealing instruction that meets requirements of specific learning goals, learners' characteristics and organizational needs.

Towards this end, the role of the instructional designers could be to create pedagogical patterns (learning designs without specific learning content), as prescriptions for designing instructional products to optimize the learning outcome. Pedagogical Patterns capture best practice in particular educational domains [Eckstein et al., 2013], assisting teachers to outline the strategies to surpass common difficulties and problems, such as how to motivate students, how to introduce new concepts or how to sequence activities, for example. These pedagogical patterns are based on instructional design theories. The teachers, based on these patterns (educational templates), can create a number of educational scenarios for various educational contexts. This involves the creation of learning activities and their connection with relevant learning contents. There is an obvious relation with architectural design patterns, as described in [Alexander, 1979], where "a pattern language gives each person who uses it, the power to create an infinite variety of new and unique buildings, just as his ordinary language gives him the power to create an infinite variety of sentences".

2.7.3.2. 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 (Table 2.2):

Table 2.2 Instructional strategies to support Honey and Mumford learning styles

Activist	*Activity-oriented* approach: showing content of activity and links to example, theory, exercise
Reflector	*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

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).

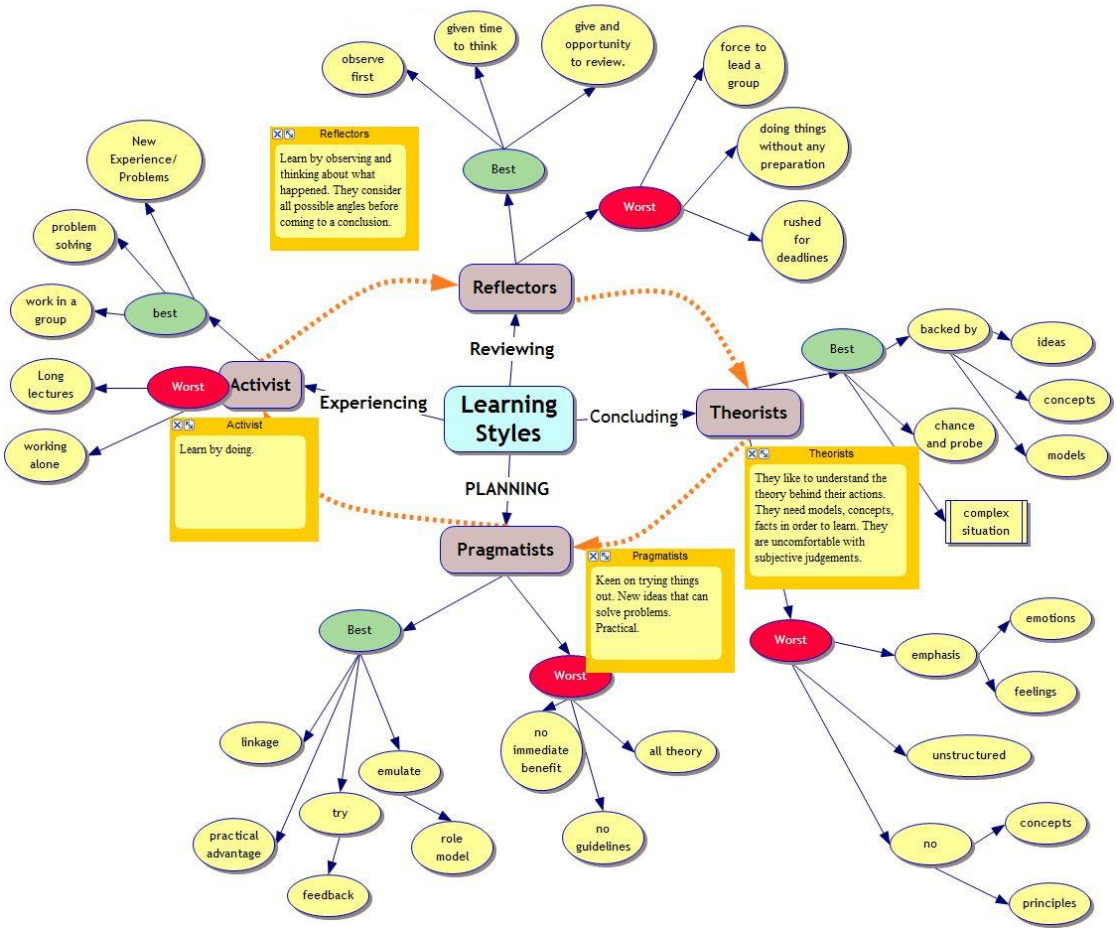

Figure 2.10 Honey and Mumford Learning Styles characteristics[3]

2.7.3.3. IMS Learning Design (IMS LD) specification

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.

[3] Retrieved from http://simonraj.com/blog/?feed=rss2

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.

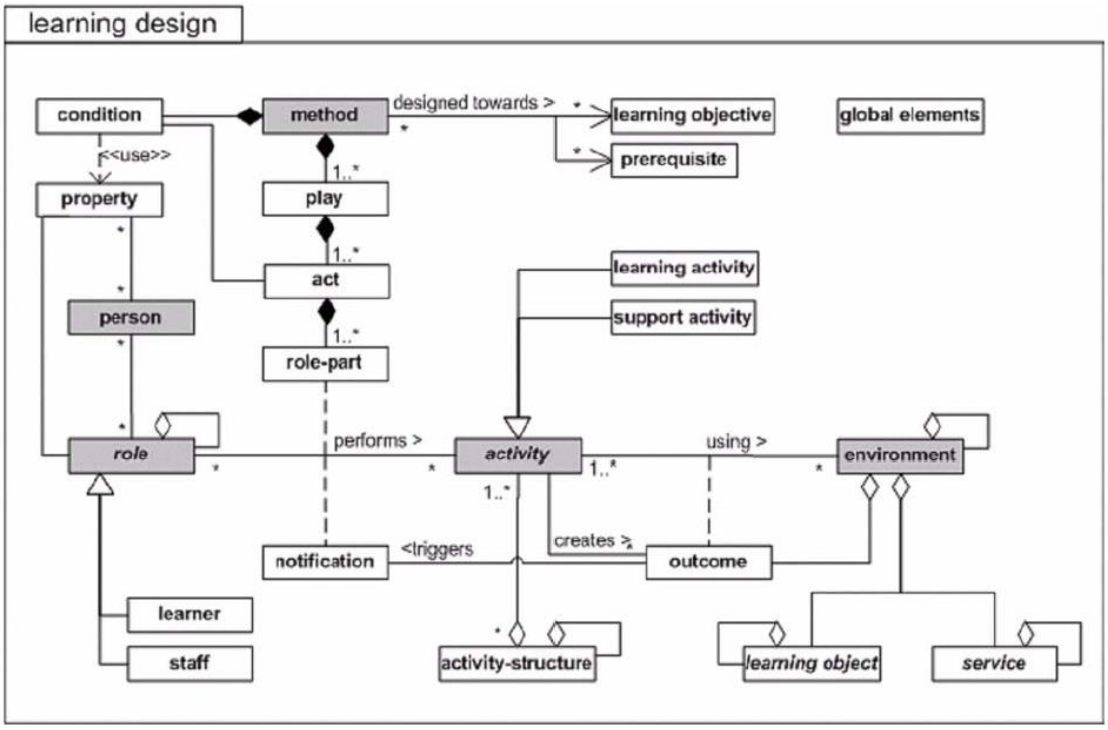

Figure 2.11 Conceptual model for overall IMS Learning Design (from [IMS LD, 2003])

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 at design time. This prohibits the construction of "real" personalized learning experiences, where appropriate learning objects according to the learner's profile are bound to the decided learning experience at 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 of learning designs that can be used from the systems as are, or parts of them for the construction of 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. 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. This instructional model for the construction of abstract training scenarios (learning designs) is based on IMS Learning Design Specification but its purpose is to overcome its limitations and complexity.

2.7.4. Approaches for adaptive personalization in eLearning

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 learning 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 learning 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 Learning 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

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.

2.8. The problem of interoperability between (cultural) digital libraries and eLearning applications

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), and semantic (inconsistencies in terminology and meanings). To support eLearning applications on top of museums cultural collections we have to deal with challenges related with all the above interoperability types, making this a complex and multilevel problem.

We could also define two axes of interoperability based on the layers of objects defined in Learnativity model as presented in Figure 2.12:

- Horizontal Interoperability: Access and use of objects at the same level, and
- Vertical Interoperability: Access, use and "transform" objects at one level to build objects at a higher level (re-purposing, contextualization)

Interoperability on both axes can be seen from the view of objects, standards, infrastructures, users and personalization.

After the analysis performed in the previous sections, we can see that to support the goal of the thesis, a complex problem of interoperability should be solved. We saw that much work has been done in terms of standards, approaches and implementations to support interoperability on the horizontal level. Main problems of interoperability arise on the vertical axis, while little work has been done in this direction. This thesis mainly deals with the vertical axis, taking also into account the related standards and work to support horizontal interoperability at each level.

In the following sections we will analyze the problem of interoperability on the vertical axis from an objects, infrastructures and personalization point of view.

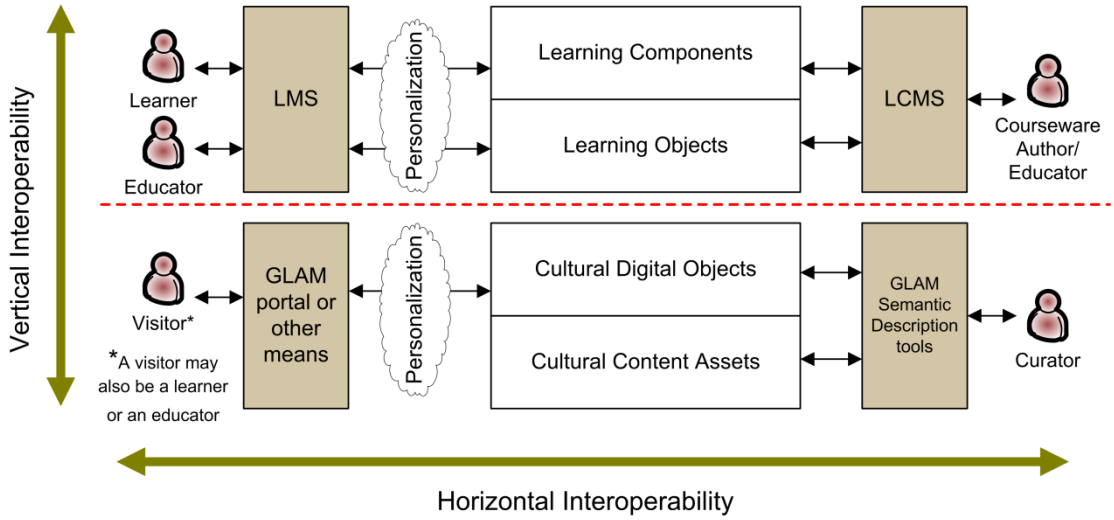

Figure 2.12 Horizontal and vertical interoperability

2.8.1. An objects point of view

A digital object can have many educational uses and these determine whether it can become a learning object or not [Warwick University group, 2004]. A digital object cannot become a learning object, unless it has a clear pedagogical purpose (learning outcome/objective) that is appropriately linked to the object through learning metadata and it has the right granularity and content for the target pedagogical purpose.

Depending on the learning context, a digital object may be appropriate or not in terms of its granularity and content to become learning object. In general, the broader the target learning objective is the bigger is expected to be the granularity of a learning object, so more than one digital objects (or parts of them) may be needed to serve this learning objective (Figure 2.13). However, we cannot predict all possible educational uses of digital objects.

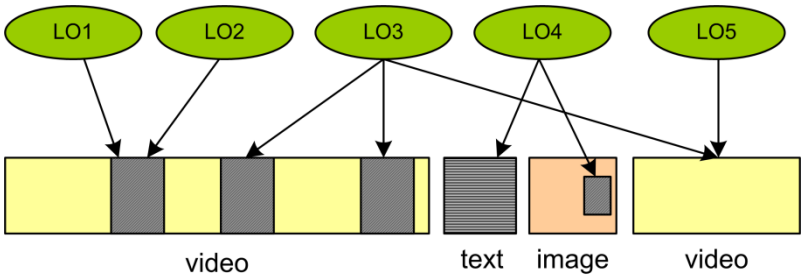

Figure 2.13 Depending on the target learning use, a digital object or parts of it may have to be combined with other digital objects or parts of them to comprise a learning object

Afterwards, these LOs should be assembled to higher level learning units (LCs). However, the way these LOs should be assembled depends on the current learning context and needs.

From the above, it turns out that transforming digital content to learning experiences is not a straightforward and one-to-one mapping process. Depending on the target educational contexts, digital content should be firstly adapted and contextualized with the use of appropriate learning metadata to form learning objects, and then used and assembled in proper ways to learning experiences taking into account the different learning needs and preferences of the target learners. This process is known as "repurposing" or "reauthoring. A repurposed or re-authored version should correspond better to the expectations, needs and interests of a target user group. To support repurposing 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. However, this re-authoring process is a multi-step and complicated activity that is not sufficiently and efficiently supported on digital libraries. As a result, both content providers and content users are not able to exploit effectively the available learning resources residing in digital libraries in various contextualized uses.

2.8.2. An infrastructures point of view

Based again on Figure 2.12 we can see the problem of interoperability of cultural digital libraries and eLearning applications from an infrastructures point of view from a top-down and bottom-up perspective.

From the perspective of (cultural) digital libraries, (cultural) digital resources are ingested and annotated by curators using different standard or non-standard schemes and/or

domain ontologies/taxonomies/vocabularies. However, these descriptions, for the context and from the point of view of curators may be not useful as they are to support different educational contexts. To be able to support learning, these cultural digital objects should be first re-purposed to create LOs and further used for the development of higher learning units to be delivered in the form of learning experiences. However, on one hand this repurposing process is not supported on top of cultural digital libraries and on the other hand museum staff, but also teachers out of the scope of these museums, lack the pedagogical knowledge to develop LOs and learning experiences to effectively support the needs and preferences of different Learners.

From the perspective of eLearning systems the authoring procedure that is currently followed for the creation of courseware is similar to the procedure followed in traditional learning environments. The author defines a number of learning objectives and activities that may be supported by LOs that should be followed in order for the target goal to be accomplished. Thereafter, the author is trying to find appropriate learning content to create learning LOs to support these activities. An author for the creation of LOs through an LCMS either discovers and reuses existing LOs that may be stored in Learning Object Repositories that (s)he repurposes depending on the target educational context or (s)he starts to create a new ones. In both cases (s)he may need to find appropriate (Cultural) Digital Objects. However, in order for these (Cultural) Digital Objects to be accessible and edited through the LCMS, they should be represented and described according to eLearning standards (e.g. SCORM, LOM) and stored in a learning objects/assets repository providing services for their discovery and access. However, although LOs must be described with educational metadata from their nature, this does not happen with cultural digital objects, which have been described from the context of the museum curator using several standard or non-standard schemes that are different from those used for the description of LOs and provided through different services (or not). For that reason, finding (Cultural) Digital Objects to be used in the construction of LOs can not be done through an LCMS, but the author has to use a number of different tools and services, e.g. those provided by GLAM web sites and/or cultural digital libraries. But even when the author finds the right cultural digital objects to be included in a LO, they will lose their useful (semantic and technical) descriptions when retrieved and incorporated in the LO. This happens because the author of the LO actually downloads 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).

2.8.3. A personalization point of view

Learners access courseware and learning experiences developed by courseware authors through LMS. In terms of personalization supported, several approaches presented have implemented in eLearning systems (but rarely integrated with LMSs), to adapt the learning experience according to the Learners' needs and preferences. However, there are several shortcomings in these approaches already described in Section 2.7.4.

In terms of access and personalization supported on top of (cultural) digital libraries, this is not (directly) targeted to learners. In (cultural) digital libraries some times personalization is considered and connected with functionality for visualization of the content e.g. by means of Linked Data or functionality provided to allow visitors (who may be also learners or teachers) create their own collections of cultural digital objects or creating their own paths on digital objects [Ferrara et al., 2013; Ferrara et al., 2014; Agirre et al., 2011; Canada museum, 2017]. However, no real-time integration of content is supported to deliver to Learners learning experiences taking into account their cognitive preferences, such as their learning styles (pedagogy-driven personalization).

2.9. The envisioned scenario of this thesis and comparison with existing approaches

The envisioned scenario of this thesis is presented in Figure 2.14. This scenario supports the thesis goal and objectives, by:

- Allowing curators, museum educators, and teachers repurposing multimedia content, to cultural digital objects, to learning objects and learning experiences.
- Helping museum educators and teachers develop pedagogically-sound personalized learning experiences to fit the needs of different learners with the use of pedagogical templates (Learning Designs) encoding instructional strategies developed by instructional design experts statically or dynamically.
- Allowing learners access learning objects and learning experiences developed by museum educators and teachers and providing them with pedagogy-driven personalized learning experiences fitting their individual needs and preferences.
- Supporting interoperability with existing LMSs, LCMSs, and repositories/aggregators.

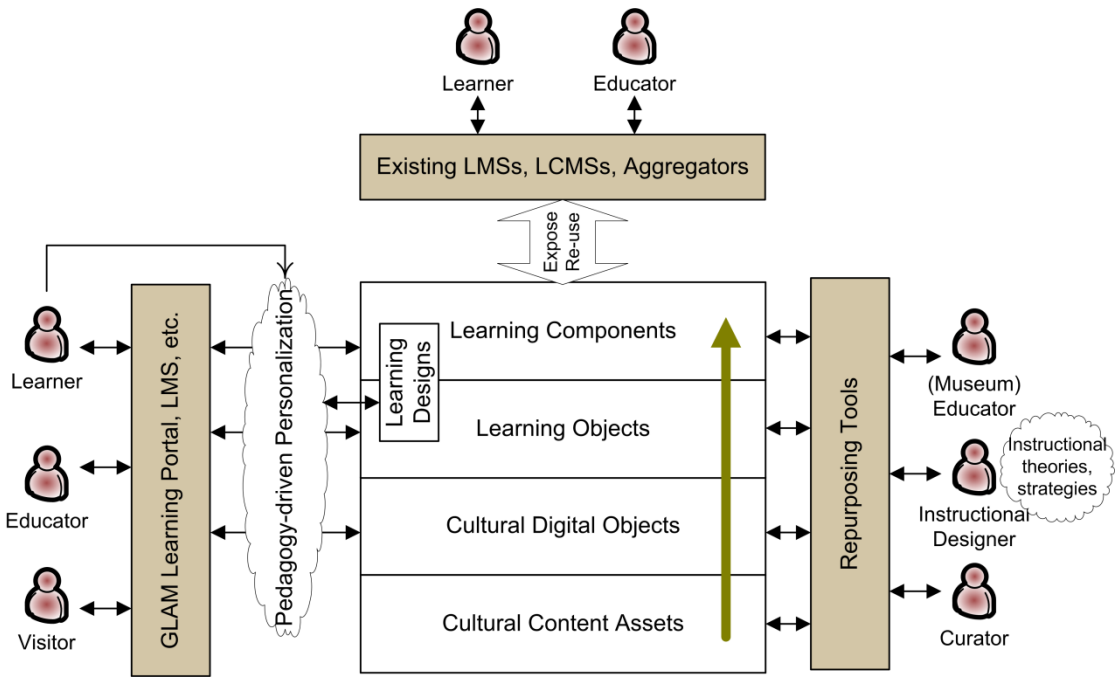

Figure 2.14 Envisioned scenario of the thesis

To my knowledge, there are no similar approaches supporting or implementing this scenario in total, except from LOGOS and Natural Europe European projects, which were based on the framework and architecture proposed in this thesis. In Chapter 5 it will be presented how the framework of this thesis was implemented in LOGOS project and applied in Natural Europe project.

So, in the next sections the envisioned scenario to be supported in this thesis is compared partially with solutions for repurposing multimedia digital objects to learning objects aiming to support eLearning applications on top of multimedia digital libraries and with solutions related with the aspect of adaptive pedagogy-driven personalization.

2.9.1. Comparison with approaches for repurposing multimedia digital objects to learning objects

To support eLearning applications on top of multimedia digital libraries there are several efforts, which, in order to re-purpose multimedia digital objects to learning objects, integrate or use in cooperation eLearning standards and A/V standards, such as 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] and [Pascual, Ferran, and Minguillón, 2006]. Most of these approaches [Amato et al., 2004; Klamma, Jarke, and Wulf, 2002] use mappings between standards (e.g. MPEG7 and LOM) or propose integration of them by adding MPEG7 elements to SCORM elements [Bush et al., 2004] or adding LOM descriptions to MPEG7 standard [Pascual, Ferran, and Minguillón, 2006]. However, as it is explained in [Yoshinov, Arapi, Christodoulakis, and Kotseva, 2016], using mappings between those standards or mixing them creating application profiles is not an efficient solution to solve the interoperability

problem between multimedia digital libraries and eLearning applications. The framework proposed in this thesis follows a different approach that is more generic and has not been developed as yet another local solution with the above problems. Moreover, 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.

2.9.2. Comparison with existing approaches for adaptive pedagogy-driven personalization

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. The thesis 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 on 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. [Karampiperis and Sampson, 2006] propose 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 proposed in this thesis does.

The closest work to the approach presented in this dissertation 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 significally 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.

2.10. Summary

In this chapter, the concepts and components of digital libraries and digital objects, as well as eLearning systems and learning objects and content were studied. Moreover, main interoperability standards, specifications and approaches for the description, packaging and access of (cultural) digital objects and learning objects, and for repositories interoperability were investigated.

Furthermore, personalization in Digital Libraries and learning were studied: user modeling and profiling; the needs and preferences of the Learner user and how they (should) affect personalization processes; the role of pedagogy and instructional design/strategies in personalization, pedagogical patterns, and IMS LD specification for instructional design; approaches for adaptive personalization in eLearning

Moreover, the complex problem of interoperablity this thesis tries to address was analyzed in detail from an objects, infrastructures and personalization point of view.

Finally, the envisioned scenario of this thesis was presented and approaches and solutions related with re-purposing of multimedia objects to learning objects and adaptive pedagogy-driven personalization) were investigated and compared with the proposed solution.

Chapter 3. MODELING THE ENVIRONMENT TO SUPPORT PEDAGOGY-DRIVEN PERSONALIZATION

3.1. Introduction

In this chapter, the modeling of the environment is described in order to support the construction and provision of pedagogy-driven personalized learning experiences [Arapi et al., 2007a; Arapi et al., 2007b; Arapi et al., 2007c, Arapi et al., 2008].

This chapter deals with pedagogical aspects and requirements for the proper description and structuring of the **domain model**, consisting of cultural Content Assets, Cultural Digital Objects, Learning Objects/Assessment Objects and Learning Components analogously to the Learnativity model as it has been presented in Chapter 2, in order to support the development of pedagogically-sound learning experiences to fit the needs and preferences of different learners, such as learning styles.

Towards this end, the application of instructional strategies to support different learning needs and contexts is of great importance. For this purpose, the thesis proposes an **instructional model** for the encoding of these instructional strategies as abstract training scenarios (Learning Designs) as prescriptions for the development of learning experiences composed of learning activities and supported by appropriate learning objects. Learning objects are not bound to these scenarios at design time, but only their characteristics are defined.

These abstract training scenarios (Learning Designs) can be exploited for the development of personalized learning experiences in a static or (automatic) adaptive way. In the first case, the educator imports these templates and uses them as a guide for the manual development of learning experiences. In the second case, an adaptation mechanism (**adaptation model**) is applied to automatically construct personalized learning experiences taking into account the current context and learning needs and preferences encoded in **Learner model** and selecting an appropriate training methods from these Learning Designs to be used thereafter to find and bind appropriate learning objects to the learning activities. This adaptation mechanism can be used both by educators for the semi-automatic construction of personalized learning experiences and Learners.

3.2. Domain modeling - From digital archives to learning experiences

We define the following types of objects based on the Learnativity model:

- **Content Assets** that correspond to raw material in digital form (images, videos, documents, etc.) coming from GLAM archives.

- **(Cultural) Digital Objects (CDOs)** that correspond to content assets or parts of them annotated and indexed with descriptive (semantic) and administrative metadata.

- The **Learning Objects (LOs)** built on top of Cultural Digital Objects and enriched with educational metadata. A learning object is a collection of Cultural Digital Objects (or only one), which 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 are also described with educational metadata.

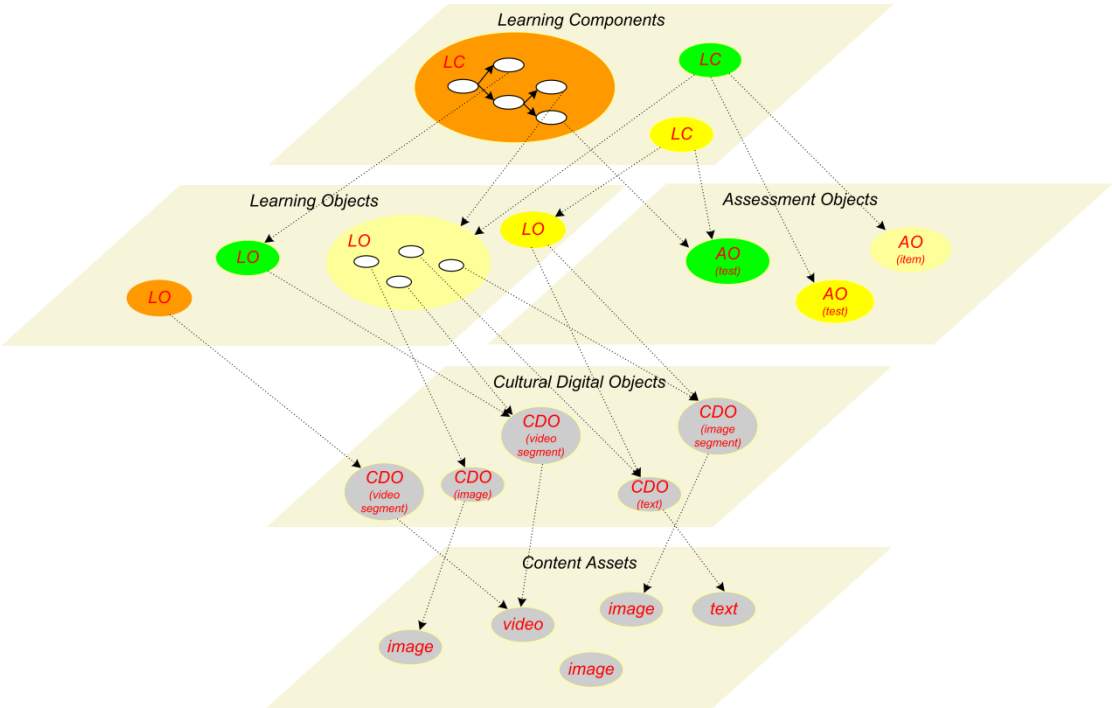

Figure 3.1 Relation among LCs, LOs, AOs, CDOs and Content Assets

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.

A flexible model that satisfies the above needs is METS [METS, 2005]. 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. Using the DMDID attribute of the 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.

This framework proposes the use of METS to support the hierarchical approach in the categorization and development of objects. 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 archives, while in parallel 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.

Figure 3.2 illustrates how METS can be used for the representation and description of LCs, LOs, AOs, CDOs and Content Assets, and their relations.

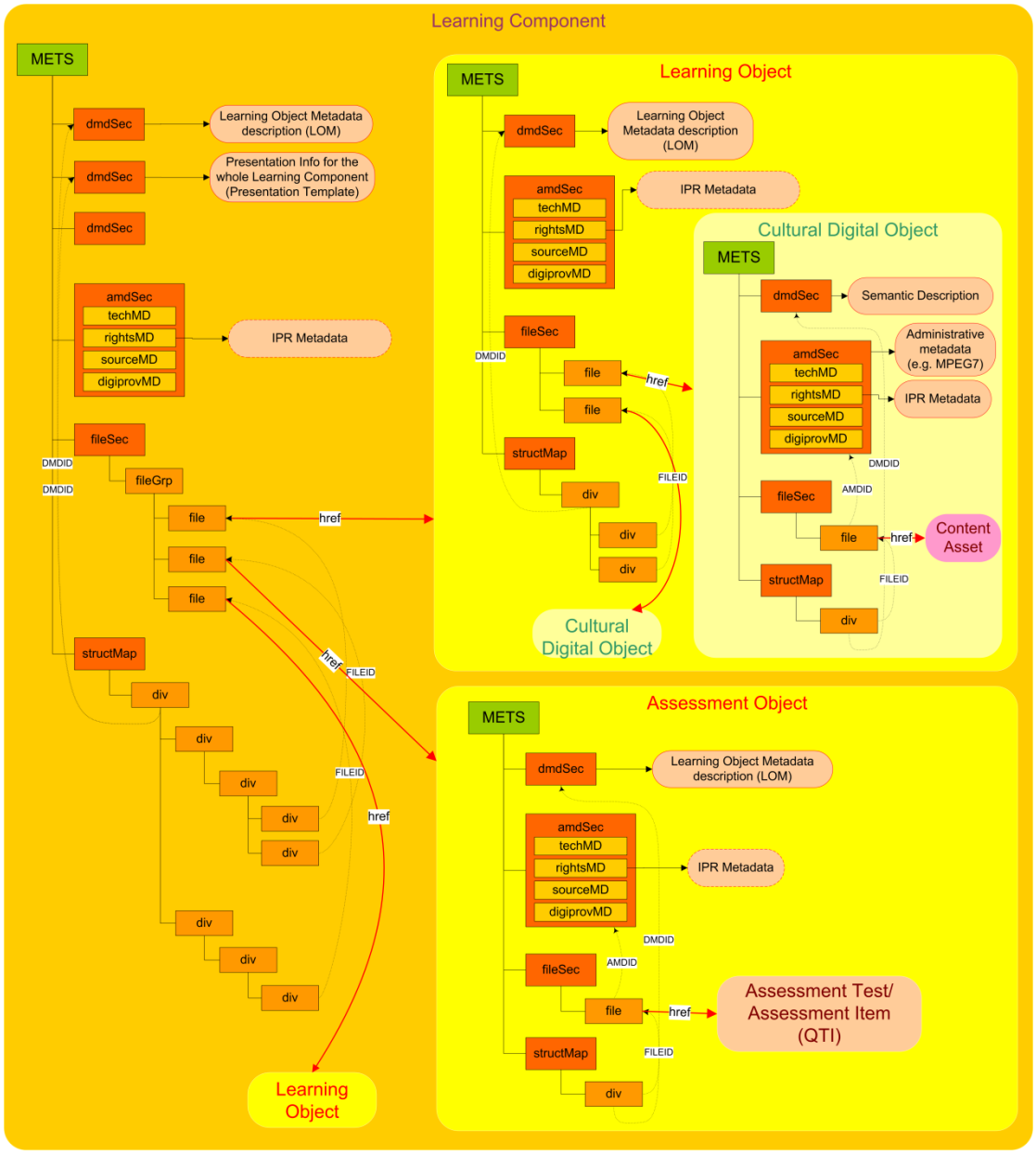

Figure 3.2 Representation of LCs, LOs, AOs, CDOs and Content Assets and their relations using METS

Cultural Digital Objects (CDOs) are described both with semantic information and administrative information. The descriptive metadata section (dmdSec) of METS is used to incorporate semantic descriptions and the administrative metadata section (amdSec) in order to incorporate administrative metadata expressed with MPEG7. The fileSec is used to point to the Content Assets, from which CDOs have evolved.

For the description of (Cultural) Digital Objects' technical characteristics MPEG7 can be used, although its use is not mandatory to apply the framework presented in this thesis. In Appendix 1.A 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 schema and an audiovisual object's description may contain much more information than this shown in these examples.

Cultural Digital Objects can be semantically described using domain ontologies, taxonomies or vocabularies alone or in combination with metadata schemes. The use of widely-accepted schemes when possible is an important step to achieve semantic interoperability.

Learning Objects (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 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 Cultural Digital Objects and the fileSec consisting of file elements is used to point to the these CDOs via identifiers. An example of a LO is given in Appendix 1.B.

Domain ontologies can also be used for the semantic description of Learning Objects, Learning Assessments and Learning Components and specifically in the formation of Learning Objectives as it is proposed later in this chapter. This is important for supporting personalization as proposed in this thesis. It is noted here that domain ontologies used for the semantic description of LOs, AOs and LCs may be different from those used for the semantic description of CDOs, since the target learning context(s) may be different from the context of the annotated CDOs.

Assessment Objects (AOs) are also described with LOM metadata via the dmdSec of METS. IMS QTI [IMS QTI, 2005] descriptions used for the representation of assessments that are referenced from the METS description.

METS is used again to integrate IMS QTI descriptions of 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 Appendix 1.C. Additionally, an example of the METS representation of an Assessment Test Object is provided, including the reference to the corresponding Assessment Test QTI description and its educational and administrative metadata.

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

An example of a Learning Component represented with METS according to the proposed framework is given in Appendix 1.D. 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.

3.2.1. The authoring process

From a user's point of view, one could imagine various authoring scenarios in order to create courseware for Learners using content residing at cultural digital 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 Cultural Digital Objects from Content Assets. This overall scenario is depicted in the activity diagram of Figure 3.3.

The editing process starts from the creation (digitization) or selection of Content Assets and the selection or creation of domain ontologies/taxonomies (i.e. conceptualizations of certain domains). These form the basis of creating Cultural Digital Objects that are further used to create higher level objects such as Learning Objects and Learning Components.

As soon as Content Assets, representing interested material coming from museums' content archives/collections, and appropriate ontologies/taxonomies are available it is possible to create Cultural Digital Objects. Cultural Digital Objects creation is essentially an activity that uses the available Content Assets in order to attach appropriate metadata to them (or parts of them) including semantic annotations that are created using the available ontologies/taxonomies.

Using the Cultural Digital Objects created, one can further create Learning Objects as collections of related Cultural Digital Objects (or from only one Cultural Digital Object) that can be used to accomplish a certain learning objective. The collection is enriched with educational metadata expressed in LOM.

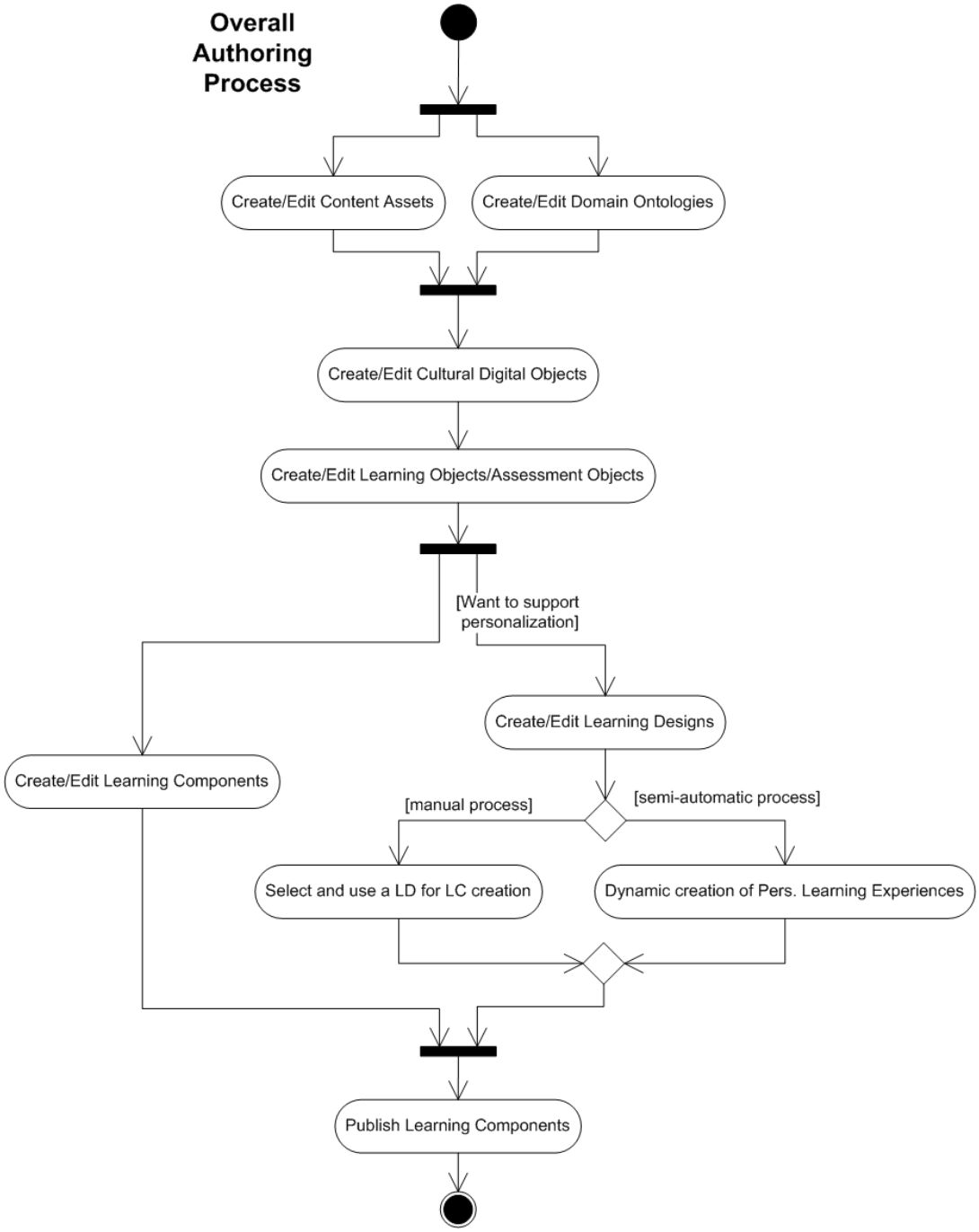

Figure 3.3 The overall authoring/repurposing process

The usage of Learning Objects in order to create Learning Components can be done in two ways (they are presented in the activity diagram as two parallel activities): First of all one can statically create Learning Components 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 (educational templates) 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. Then, two scenarios are possible for the author:

1) Use an existing Learning Design depending on the target learner needs to guide the creation of the Learning Component (manual process).

2) Use the dynamic creation of personalized learning experiences feature where the binding of training activities with the Learning Objects is done by an automatic mechanism that is able to create personalized learning experiences exploiting information about the learner characteristics (this information can come from a Learner Profile). This is a semi-automatic process.

The final activity in the authoring process is the storage or publishing of Courseware Objects in order to be ready for consumption by the Learners.

3.2.2. Pedagogical aspects of learning/assessment objects to support personalization

Learning Objects are built in order to fulfil certain learning objectives, while Assessment Objects are built and used to assess the satisfaction of learning objectives. 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 them[4]. In this framework we argue that ideally for each Learning Objective there must be at least one Assessment Object being able to evaluate in what extend a Learner has achieved it.

In order to support personalization as proposed in this framework it is important to consider some pedagogical properties for the description of Learning Objects and Assessment Objects.

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

[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.

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 objectives 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 3.1 shows how this element can be adapted in order to represent a specific Learning Objective.

Table 3.1 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 also been considered as an important parameter when performing personalization. Similarly, the classification element of LOM can be used for the Educational Level of Learning Objects. Table 3.2 shows how the classification element of LOM can be used in order to include info about the intended educational level of the current learning object:

Table 3.2 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 support different learning styles and perform adaptive selection of learning objects as proposed in this framework, this framework uses the following elements of LOM, as the most appropriate ones for this purpose: learning resource type, interactivity type, interactivity level, and semantic density, in addition to the learning objective as described before using classification element.

- **educational.learningResourceType**: Specific kind of learning object. The most dominant kind shall be first. Values: exercise, simulation, questionnaire, diagram, figure, graph, index, slide, table, narrative text, exam, experiment, problem statement, self assessment, lecture.

- **educational.interactivityType**: Predominant mode of learning supported by this learning object. Values: active, expositive, mixed.

  "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.

"Expositive" learning (e.g., passive learning) occurs when the learner's job mainly consists of absorbing the content 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. When a learning object blends the active and expositive interactivity types, then its interactivity type is "mixed". Examples of active documents (with learner's action) are: simulation (manipulates, controls or enters data or parameters), questionnaire (chooses or writes answers), exercise (finds solution), and problem statement (writes solution). Examples of expositive documents: hypertext document (reads, navigates), video (views, rewinds, starts, stops), graphical material (views), audio material (listens, rewinds, starts, stops). An example of mixed document is a hypermedia document with embedded simulation applet.

- **educational.interactivityLevel**: 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. Values: very low, low, medium, high, very high. Learning objects with 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 interactivityType="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).

- **educational.semanticDensity**: 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. Values: very low, low, medium, high, very high.

Using these elements in learning objects' metadata for their adaptive selection according to learning styles, learning objects remain independent from the learning style approach used and can be re-used to support different learning style categorizations and learning scenarios. 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 to support other learning style categorizations.

To support a specific learning style, appropriate learning objects should be constructed according to the specific characteristics of each learning style. This also affects the selection of the Learning Objects' underlying content (Digital Objects). Using appropriate combinations of the values of LOM metadata elements selected (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.

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.

3.3. Learner modeling

The parameters described in Chapter 2 as important to personalization processes and their relations are normalized within the conceptual model illustrated in Figure 3.4. These can be considered as a part of a Learner Profile, since they describe in some extent a Learner. A Learner Profile may contain more information, but here we just focus on what is considered as important in this framework 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.

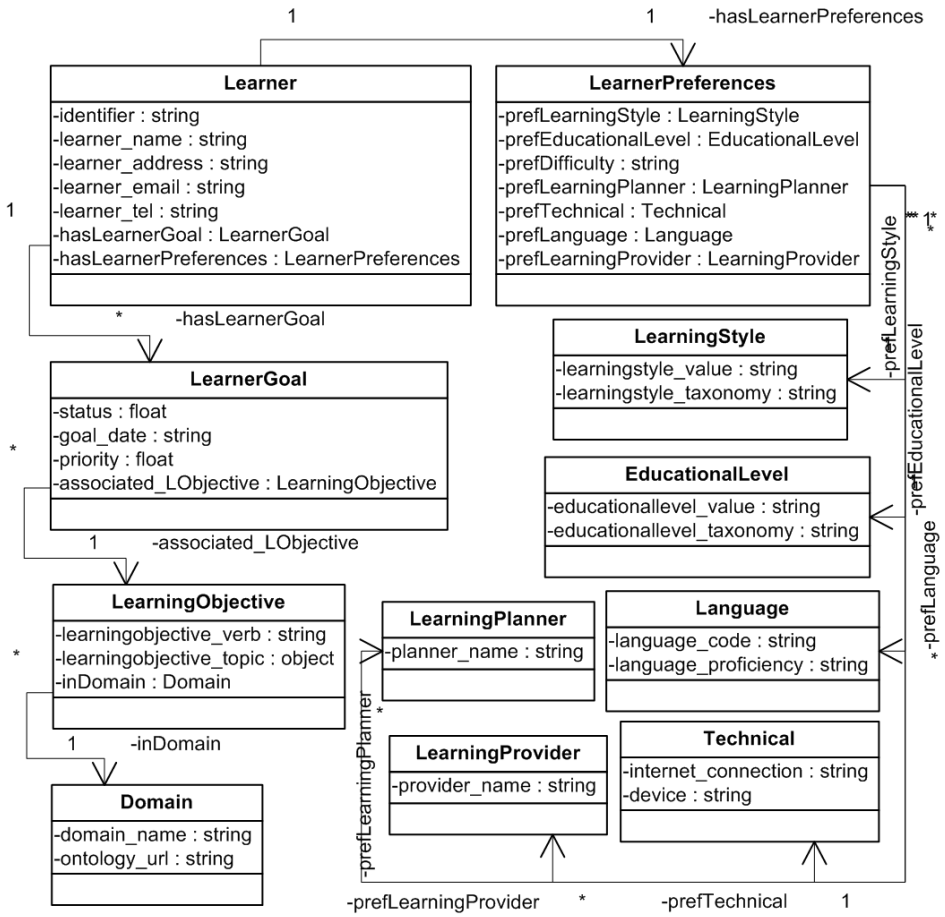

Figure 3.4 Learner Profile classes related with the dynamic creation of personalized learning experiences

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 [Karagiannidis and Sampson, 2004]. 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 into 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".

Honey and Mumford Learning Style Questionnaire can be used for the identification of the Learning Style of the Learner according to Honey and Mumford's classification. However, this questionnaire is quite long as it contains 80 questions. A shortened version of the questionnaire would be more appropriate and the Learners would be more willing to complete it. For example, IBM used a shortened version to investigate the learning styles of 365 of their managers [Honey et. al, 1992]. Another version of the questionnaire was created in 3DE project [Del Corso et. al, 2003], containing 36 questions, and this thesis uses it since it can be easily completed by the Learners while in parallel gives very good results. This questionnaire is provided in Appendix 5.

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

Table 3.3 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>Vasso Arapi</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. An approach and corresponding functionality for the development and update of Learner Profiles and its

integration with LMS is presented in Chapter 5/Appendix 4 in the case of LOGOS project.

3.4. Instructional modeling - Learning Designs

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. 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 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.

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. The approach proposed in this thesis 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 3.5.

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.

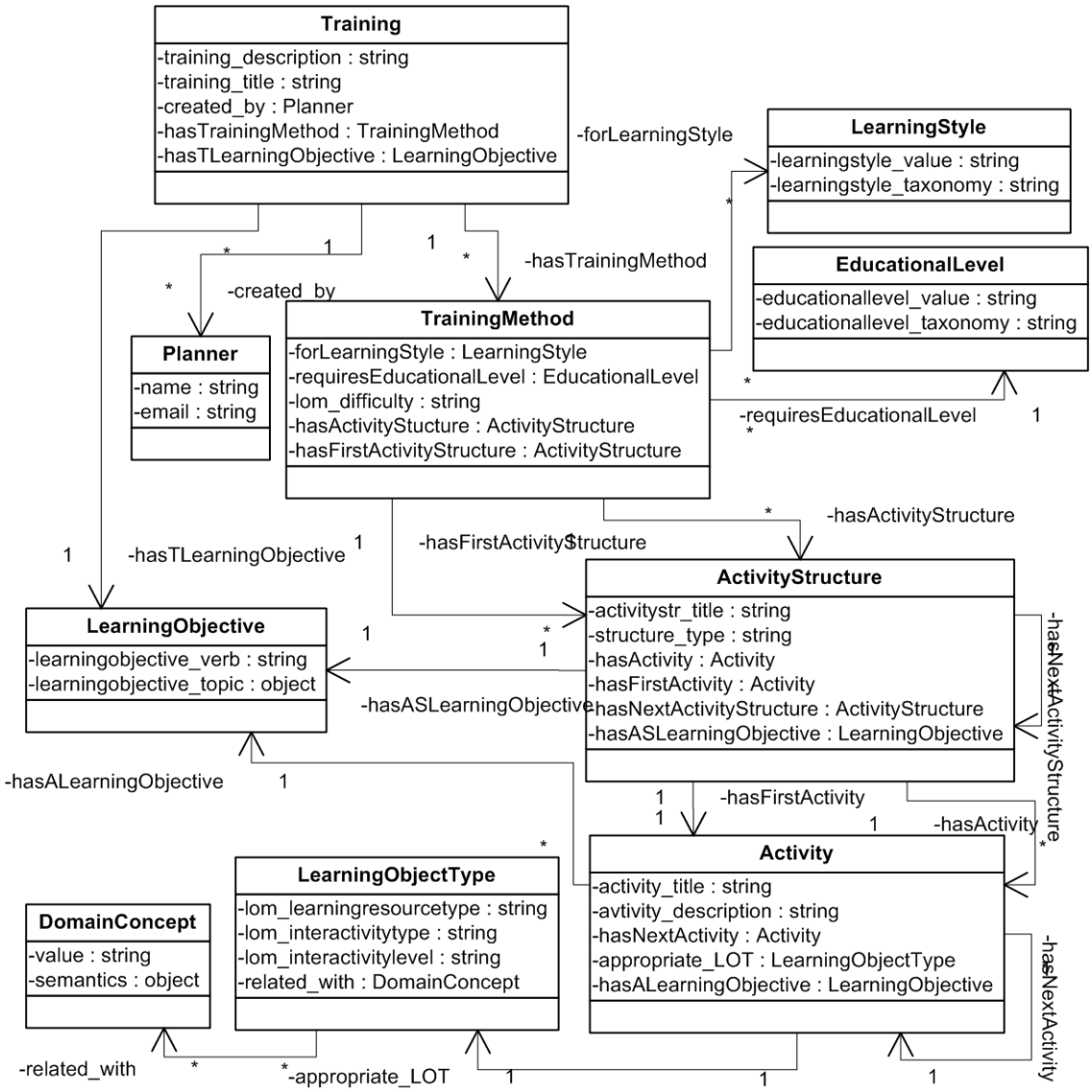

Figure 3.5 The instructional model used in the construction of Learning Designs

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 also be 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, 2007b] could be used to form such a query.

An example of a Learning Design for teaching the basic concepts of SCORM is given in Table 3.4. This Learning Design is represented using XML.

Table 3.4 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>
                <value>GeneralToSpecific</value>
          </learningStyle>
          <educationalLevel>
              <source>http://…/educationallevels.owl</source>
              <value>Further</value>
          </educationalLevel>
          <difficulty>medium</difficulty>
          <activityStructure id="AS1" lobjectiveref="LVAS1" 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="LVAS2" 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="LVAS3" 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="LVAS1">
      <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>
```

In the following sections the development of Learning Designs to support all Honey and Mumford' learning styles 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.

3.4.1. 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.

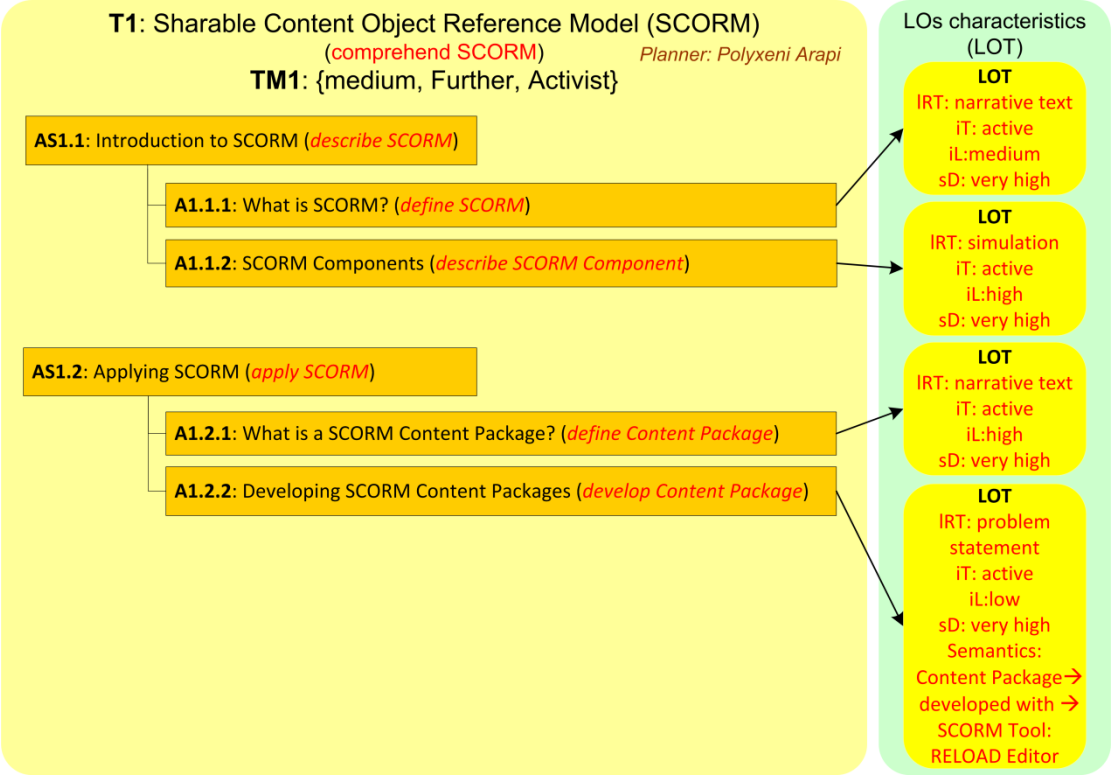

Figure 3.6 Training Method for Activists

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, simulations/games (learning Resource Type: simulation) 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 expositive role).

In Figure 3.6 a sample of a training method for teaching SCORM to Activists is illustrated.

3.4.2. 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.

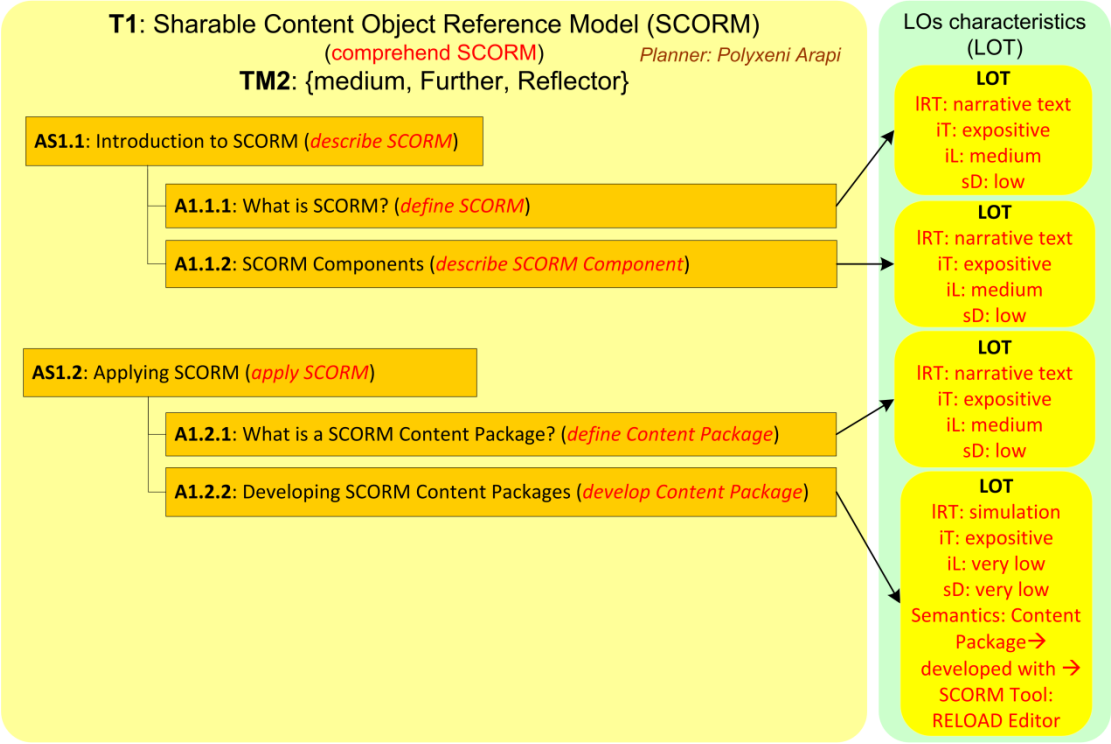

Figure 3.7 Training Method for Reflectors

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: low).

In Figure 3.7 a sample of a training method for teaching SCORM to Reflectors is illustrated.

3.4.3. 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 (i.e., 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.

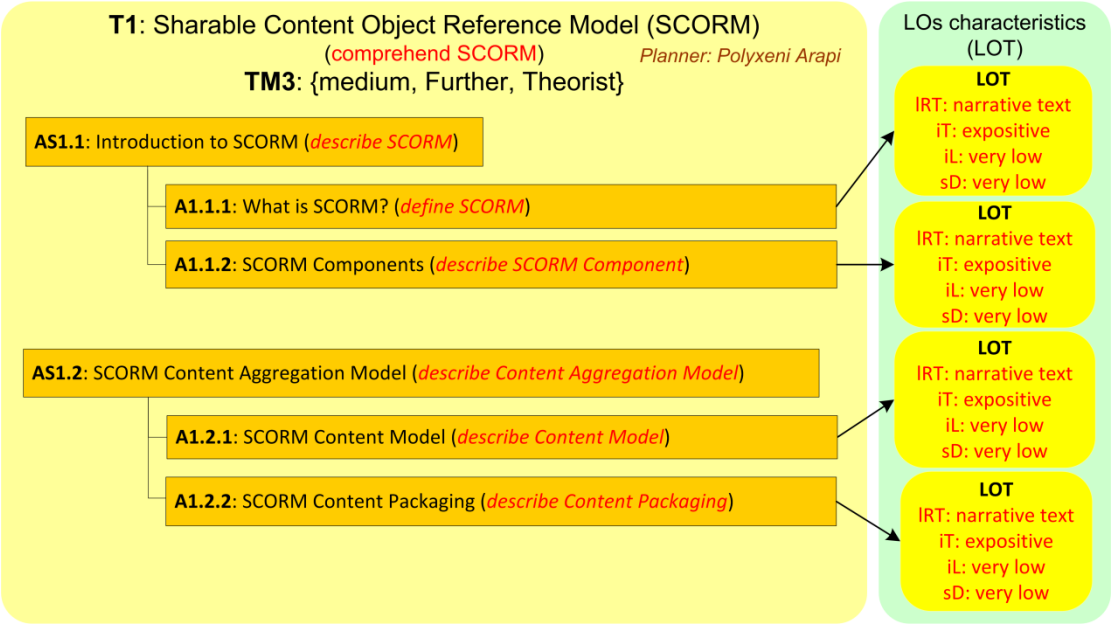

Figure 3.8 Training Method for Theorists

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 3.8 a sample of a training method for teaching SCORM to Theorists is illustrated.

3.4.4. 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 applicaple 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.

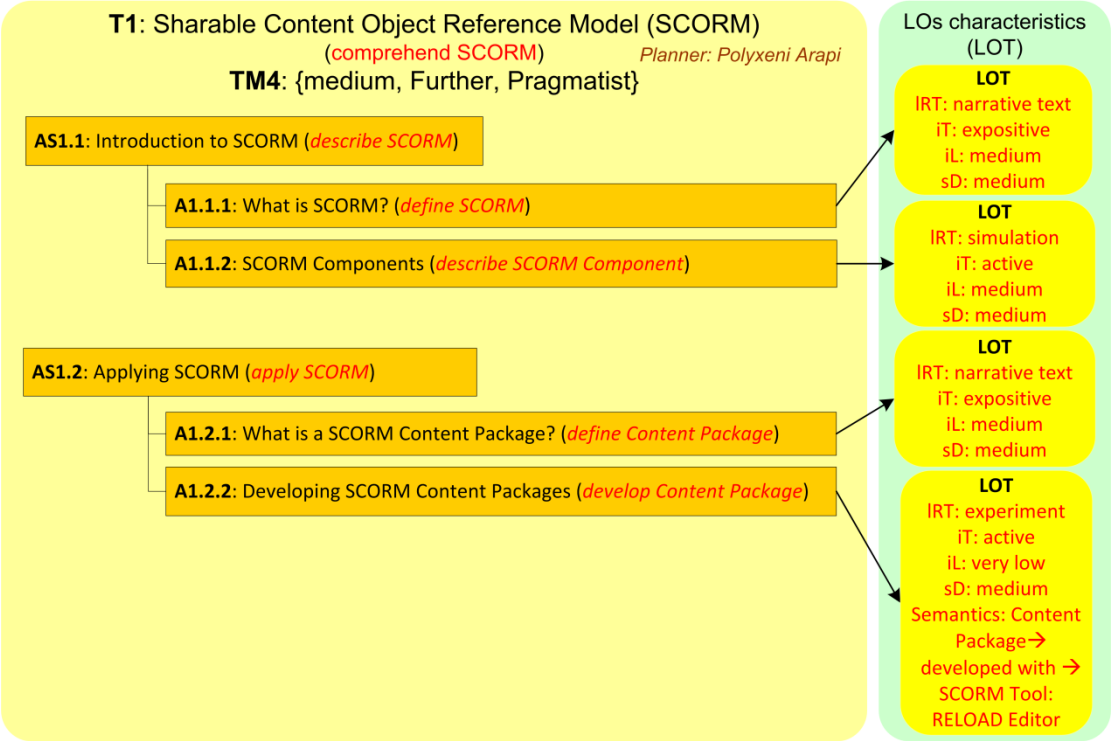

Figure 3.9 Training Method for Pragmatists

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 3.9 a sample of a training method for teaching SCORM to Pragmatists is illustrated.

3.5. Adaptation modeling

The adaptation mechanism takes into account the knowledge provided in the Learner model and the available Learning Designs to dynamically create personalized learning experiences. 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. Appropriate learning objects are bound to the learning scenario at run-time. The generated learning experiences are stored as Learning Components and they can be further transformed to SCORM packages for their delivery to eLearning systems.

The procedure of constructing an adaptive learning experience is illustrated in Figure 3.10. In each step several parameters of the Learner Profile and current context (given in brackets in Figure 3.10) are taken into account:

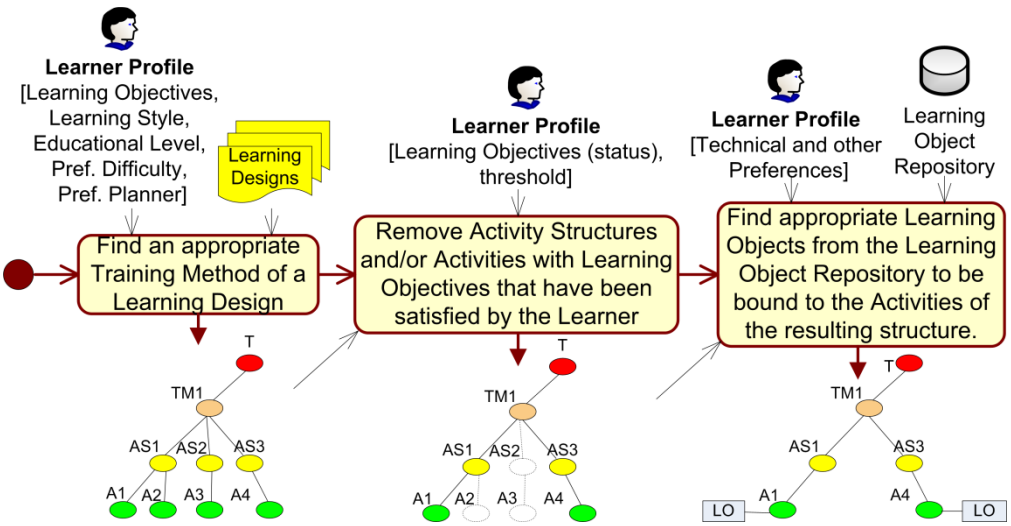

Figure 3.10 The procedure of dynamic construction of personalized learning experiences

Step 1: Selection of an appropriate Training Method

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.

Step 2: Refinement of the selected Training Method

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 in the past (previous knowledge). A threshold t can be defined so that Learning Objectives with satisfaction value greater than this threshold can be considered as satisfied.

Step 3: Retrieval of appropriate Learning Objects

Finally, appropriate learning objects are retrieved and bound to each node (Activity) of this structure constructing the learning experience, taking into account the learning object characteristics defined in each learning activity of the selected and refined Learning Design and the technical and other preferences of the Learner.

These steps are described in detail in the following sections.

3.5.1. Selection of an appropriate training method

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 3.5 shows the elements that are matched between the Learner Profile and the candidate Learning Designs during this process.

Table 3.5 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/EducationalLeverl[@educationallevel_taxonomy, @educationallevel_value]	Training/hasTrainingMethod/TrainingMethod requiresEducationalLevel/EducationalLeverl[@educationallevel_taxonomy, @educationallevel_value]
Learner/hasLearnerPreferences/LearnerPreferences/@prefDifficulty	Training/hasTrainingMethod/TrainingMethod[@lom_difficulty]
Learner/hasLearnerPreferences/LearnerPreferences/prefLearningPlanner/LearningPlanner[@planner_name]	Training/created_by/Planner[@name,@string]

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:

$w_{LV} = \frac{\sum_{i=1}^{n} p_i}{n}$, where $p_1, \ldots, p_n$ 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:

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

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:

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

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 $f(x) = \begin{cases} 0, & x \le 0 \\ 1, & x > 0 \end{cases}$.

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.

As an example, let's assume that we have the following information in the Learner model in terms of his/her target goals and priorities set, and previous knowledge (status - achievement of these learning objectives).

Table 3.6 Updated Learning Objectives and target goals in Learner Profile after previous knowledge testing

Selected Learning Objectives (Learner Goals)	verb	topic	Status (Previous knowledge)	priority
√	comprehend	SCORM	0.3	0.5
	define	SCORM	1.0	0.0
	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	0.0
√	apply	SCORM	0.0	1.0

Let's also assume that the Learner has the following preferences:

Table 3.7 Learner's Preferences

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

Finally, let's assume that we have available the four training methods presented in Section 3.4. For these methods and given the above information in the Learner model, w_{LV} representing the degree of satisfaction of Learner's Learning Goals from the Learning Objectives associated (indirectly) with the Training Method will be calculated as follows:

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

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

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

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.

Consider the following values for Educational Level: Primary, Middle, Secondary, Further, Higher Education. To compute w_D 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 3.8.

Table 3.8 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

So, 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 3.9.

Table 3.9 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 3.10 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.

3.5.2. 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 greated than the threshold (threshold=0.5), as illustrated in Figure 3.11.

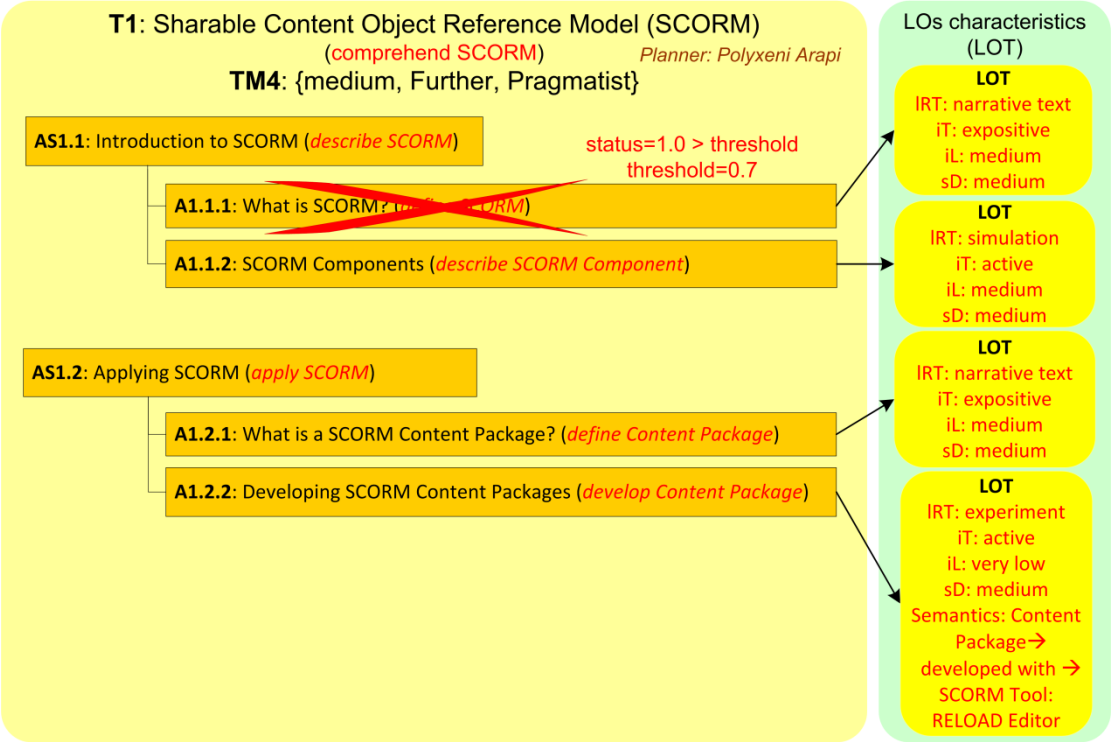

Figure 3.11 Refined training method structure

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

The next step is to retrieve appropriate learning objects to be bound to the activities of the refined training method structure. 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.

Table 3.11 Matching between Learning Design Properties and Learning Objects Metadata

Training/TrainingMethod/ActivityStructure/Activity/LearningObjectType/lom_learning_ResourceType	lom/educational/learning_ResourceType
Training/TrainingMethod/ActivityStructure/Activity/LearningObjectType/lom_interactivityType	lom/educational/interactivityType
Training/TrainingMethod/ActivityStructure/Activity/LearningObjectType/lom_interactivityLevel	lom/educational/interactivityLevel
Training/TrainingMethod/ActivityStructure/Activity/LearningObjectType/lom_semanticDensity	lom/educational/semanticDensity
Training/TrainingMethod/ActivityStructure/Activity/LearningObjective/verb	lom/classification/taxonpath[1]/taxon/entry/string
Training/TrainingMethod/ActivityStructure/Activity/LearningObjective/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 properties of the learning objects are taken into account as previously presented. All these properties (LOM elements) are summarized again in Table 3.12. Properties that are related with the context of use of those learning objects (e.g. technical) that come from the Learners' preferences can also be taken into account, but here we focus on properties related with the pedagogical aspects of learning objects.

Table 3.12 Important Learning Objects Metadata and corresponding values

Abbreviation	LOM metadata	values
lrT	Learning Resource Type	exercise, simulation, questionnaire, diagram, figure, graph, index, slide, table, narrative text, exam, experiment, problem statement, self assessment, lecture.
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)	

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 (Appendix 2). 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∈Q for each Learning Object o∈O. This function is defined recursively as follows:

- $$F(\langle t_1, w_1 \rangle OR \ldots OR \langle t_N, w_N \rangle, o) = \left(\frac{\sum_{i=1}^{N} F(t_i, o)^p \cdot w_i^p}{\sum_{i=1}^{N} w_i^p} \right)^{1/p}$$

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

An example of the fuzzy filter that is used for the retrieval of appropriate learning objects for an activity is given in Figure 3.12. 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):

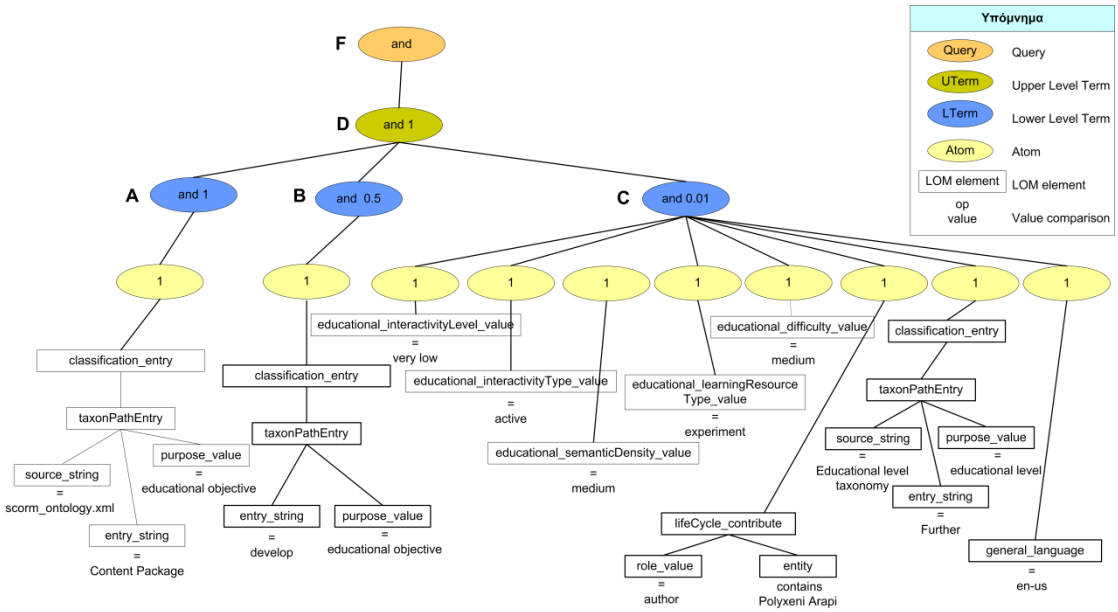

Figure 3.12 Example of fuzzy filter used for the retrieval of appropriate learning objects for an activity

The weights on the LTerm nodes have been appropriately selected in order to retrieve only learning objects that at least satisfy the Leaning 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 3.13 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 3.13, which in this case means that it satisfies at least the current activity's Learning Objective.

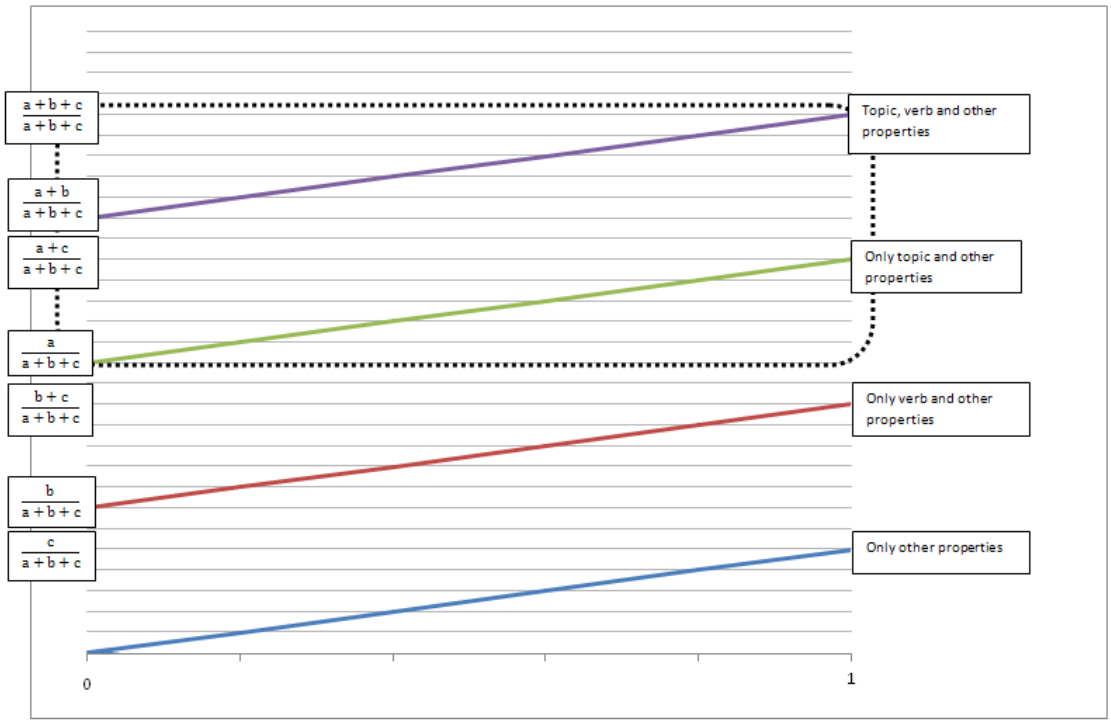

Figure 3.13 Categorization of learning objects (LO ids in the horizontal axis) depending on their weight (vertical axis) as candidates to get bound to an activity or not

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 3.12 for this learning object we do the following:

- F(<classification_entry>)=1 since
    - F(<taxonPathEntry>)=1 since
        - F(<source_string,=,scorm_ontology.xml>,o1)=1
        - F(<entry_string,=,Content Package>,o1)=1
        - F(<purpose_value,=,educational objective>,o1)=1
- F(<classification_entry>)=1 since
    - F(<taxonPathEntry>)=1 since
        - F(<entry_string,=,develop>,o1)=1
        - F(<purpose_value,=,educational objective>,o1)=1
- F(<educational_interactivityLevel,=,low>,o1)=0
- F(<educational_interactivityType,=,active>,o1)=1
- F(<educational_semanticDensity,=,very high>,o1)=0
- F(<educational_learningResourceType,=,problem statement>,o1)=0
- F(<educational_difficulty,=,medium>,o1)=1
- F(<lifeCycle_contribute>)=1 since
    - F(<lifeCycle_contribute_role_value,=,author>,o1)=1
    - F(<lifeCycle_contribute_entry,=,Polyxeni Arapi>,o1)=1

- F(<classification_entry>)=0 since
  - F(<taxonPathEntry>)=0 since
    - F(<source_string,=,Educational Level Taxonomy>,o1)=1
    - F(<entry_string,=,Higher Education>,o1)=0
    - F(<purpose_value,=,educational level>,o1)=1
- F(<general_language,=,en-us>,o1)=1

Then, the following equations hold:

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

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

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

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

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

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

For p=1 the above formula gives approximately:

F(f1,o1) =0.9966887417218543046357615894 04

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,o2), learning object o2 will be bound to the current activity as the most appropriate one.

For the needs of our example let's consider that the learning objects presented in Annex 3 have been developed. A number of learning objects with the same learning objective but different properties 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 semantically described with the simple ontology presented in Appendix 3 describing the SCORM domain. Beyond the important metadata presented earlier, this information is also used when learning object are filtered by the adaptation component to match the requirements of activities in a Learning Design (via the related_with property). Normally, all learning objects contain digital objects that are semantically annotated, but for simplicity, in the learning objects of this example only the annotations that will match the identified needs during the personalization are presented.

In order to find the most appropriate learning object for the activity A1.2.2 of the refined structure of TM4 (Figure 3.9), a fuzzy filter is constructed which happens to be the same with those depicted in Figure 3.12.

The same filter is represented in Table 3.13 in XML format.

Table 3.13 Fuzzy filter for the retrieval of learning objects for the activity A1.2.2 of TM4

```
<FuzzyQuery type="and">
   <FuzzyUterm type="and" weight="1.0">
    <FuzzyLterm type="and" weight="1.0">
      <FuzzyAtom weight="1.0">
       <classification_entry>
         <taxonPathEntry>
           <source_string op="=">scorm_ontology.xml</source_string>
           <taxon_entry>
            <entry_string op="=" language="en">Content Package</entry_string>
           </taxon_entry>
         </taxonPathEntry>
         <purpose_value op="=">educational objective</purpose_value>
       </classification_entry>
      </FuzzyAtom>
    </FuzzyLterm>
    <FuzzyLterm type="and" weight="0.5">
      <FuzzyAtom weight="1.0">
       <classification_entry>
         <taxonPathEntry>
           <taxon_entry>
            <entry_string op="=">develop</entry_string>
           </taxon_entry>
```

```
          </taxonPathEntry>
          <purpose_value op="=">educational objective</purpose_value>
        </classification_entry>
      </FuzzyAtom>
    </FuzzyLterm>
    <FuzzyLterm type="and" weight="0.01">
      <FuzzyAtom weight="1.0">
        <educational_interactivityLevel_value op="=">very
low</educational_interactivityLevel_value>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <educational_interactivityType_value
op="=">active</educational_interactivityType_value>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <educational_learningResourceType_value
op="=">experiment</educational_learningResourceType_value>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <educational_semanticDensity_value
op="=">medium</educational_semanticDensity_value>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <educational_difficulty_value
op="=">medium</educational_difficulty_value>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <general_language op="=">en-us</general_language>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <lifeCycle_contribute>
          <role_value op="=">author</role_value>
          <entity op="contains">Polyxeni Arapi</entity>
        </lifeCycle_contribute>
      </FuzzyAtom>
      <FuzzyAtom weight="1.0">
        <classification_entry>
          <purpose_value op="=">educational level</purpose_value>
          <taxonPathEntry>
            <source_string op="=">Educational level taxonomy</source_string>
            <taxon_entry>
             <entry_string op="=">Further</entry_string>
            </taxon_entry>
          </taxonPathEntry>
        </classification_entry>
      </FuzzyAtom>
    </FuzzyLterm>
   </FuzzyUterm>
</FuzzyQuery>
```

After the execution of the query in the learning object repository the learning objects presented in Table 3.14 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 3.14 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	0.9966887417218543046357615894039 74
kdc-f413-034	Packaging courses with SCORM	0.9966887417218543046357615894039 74
jkg-c511-906	Inside a SCORM Content Package	0.6655629139072847682119205298014 00
ffc-g511-425	SCORM Content Packaging	0.6655629139072847682119205298014 00
gkc-n311-439	SCORM content packages	0.6647350993377483443708609271524 00

Similarly, appropriate learning objects are found for the other activities of the refined structure of TM4 and the result is illustrated in Figure 3.14.

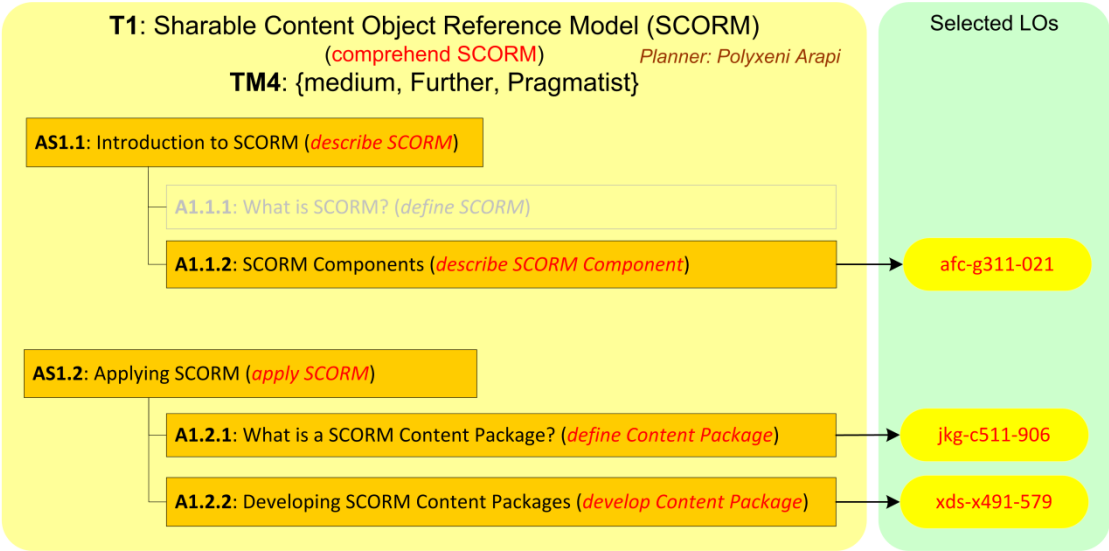

Figure 3.14 Final structure after the binding of the most appropriate learning objects in TM4 activities

The intermediate format of the learning experience generated as a result of the personalization process described in the previous section is stored as a Learning Component in the METS-based representation and it can be further transformed to a SCORM Package for its delivery to LMS and other eLearning applications.

The exact transformation process and mechanism will be presented in detail in Chapter 4.

3.5.4. Use of the same algorithm for Learner's previous knowledge identification

The algorithm presented can be used in a similar way for the creation of Assessment Tests in order to evaluate the previous knowledge of the Learner and update his/her Learner profile.

Let's assume that the Learner has the same target learning goals as in the example presented in Section 3.5.1, but its previous knowledge expressed in terms of learning objectives satisfaction (status) is different, as presented in the following table.

Table 3.15 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

TM4 will be selected again according to the target goals of the Learner but now it will be 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 in what extent 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.

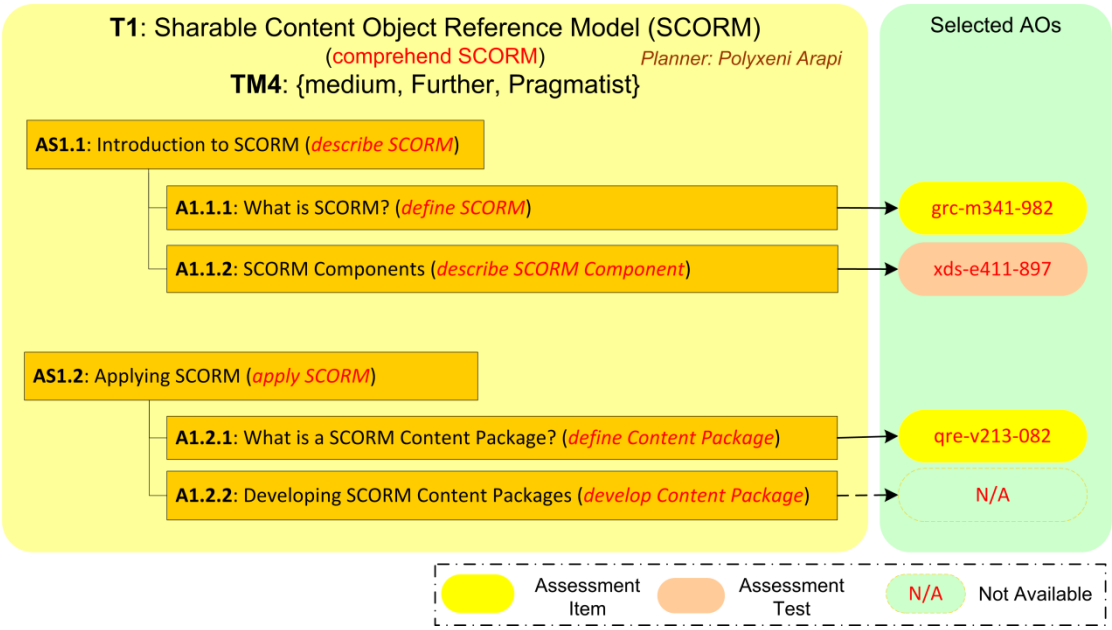

Figure 3.15 Assessment Objects found and bound to TM4 activities forming the Assessment that will evaluate Learner's knowledge

For the needs of this example let's assume that the Assessment Objects presented in Table 3.16 have been developed. 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 3.16 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	lRT: exercise lobv: define SCORM diff: medium el: Higher Education
lvc-e353-943	Which from the following are SCORM Components?	N/A	lRT: exercise lobv: list SCORM diff: medium el: Higher Education
hft-r456-242	What is the SCORM Content Aggregation Model?	N/A	lRT: exercise lobv: describe Content Aggregation Model diff: medium el: Higher Education
qvc-r331-921	What is the SCORM Run-Time Environment?	N/A	lRT: 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)	lRT: questionnaire lobv: describe SCORM Component diff: medium el: Higher Education
qre-v213-082	What is a SCORM Content Package?	N/A	lRT: exercise lobv: define Content Package diff: medium el: Higher Education
uec-w311-123	What are the parts of a SCORM	N/A	lRT: exercise

	Content Package?		lobv: list Content Package diff: medium el: Higher Education
mlk-e351-148	What is a Package Interchange File (PIF)?	N/A	lRT: 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)	lRT: questionnaire lobv: describe Content Packaging diff: medium el: Higher Education

The Assessment Objects selected after this process are presented in Figure 3.16 which also shows the exact structure of the generated Assessment.

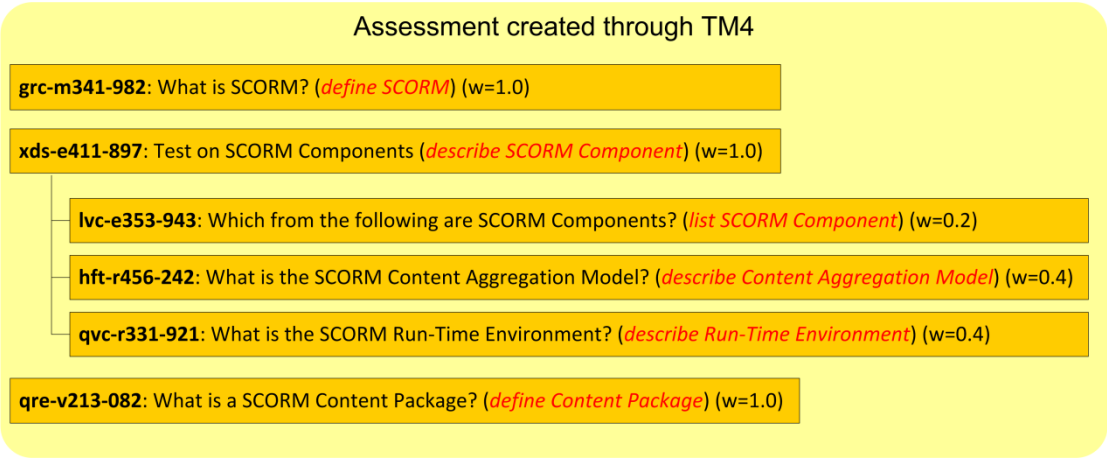

Figure 3.16 Final Assessment created through training method TM4

The Learner answers the questions of the Assessment as illustrated in Figure 3.17.

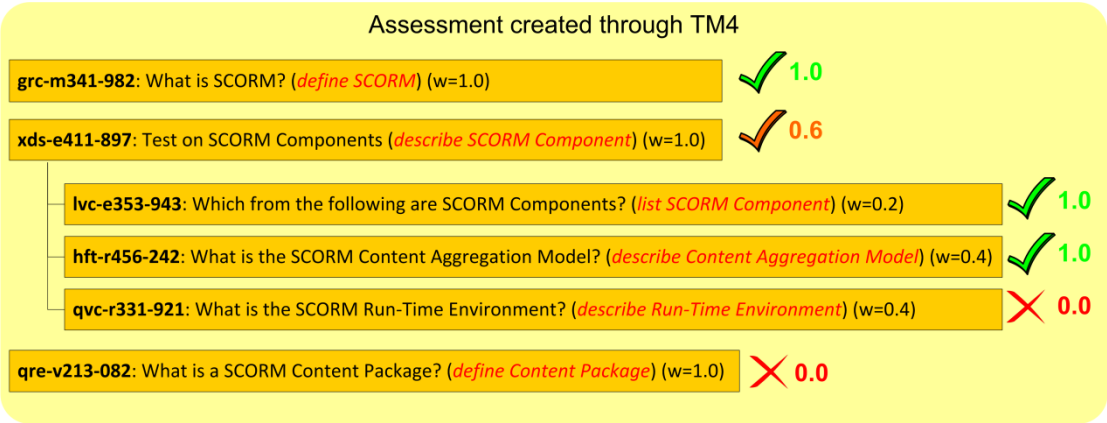

Figure 3.17 Assessment completed by the Learner and score for each learning objective associated with questions (Assessment Items) or questionnaires (Assessment Tests)

After the completion of the Assessment by the Learner, the Learning Objectives in his/her profile are updated as illustrated in Table 3.17.

Table 3.17 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

3.6. Summary

This chapter presented the modeling of the environment in order to support repurposing of cultural digital content to pedagogically-sound personalized learning experiences. Towards this end it defined and described the following models:

- Domain model: Following the Learnativity Model it was defined how learning experiences can be gradually developed from digital content assets coming from GLAM archives. Such a categorization is important to define the granularity of these objects and their characteristics to support personalization. The detailed representation of these objects and their relations was developed using METS digital library standard as the basis for combining various schemata necessary to describe Digital Objects, reusable Learning Objects, Assessment Objects and Learning Components. LOM was selected for the representation of educational metadata for both Learning Objects and Learning Components. Semantic metadata can be represented using several metadata schemes, domain ontologies, taxonomies or vocabularies. The authoring/repurposing process and pedagogical aspects and requirements for the proper description and structuring of the object layers to support pedagogy-driven personalization were also described.

- Learner model: The learner characteristics identified in Chapter 2 as important parameters to support personalization were modeled. These are exploited during the dynamic creation of personalized learning experiences in order to select appropriate training scenarios to guide the learning experiences creation process and furthermore to select appropriate reusable Learning Objects to be linked with learning activities in order to create personalized learning experiences.

- Instructional model: The pedagogy-driven personalization is based on abstract training scenarios that capture the pedagogical approached to teach a subject taking into account the individual learning styles, educational level, preferred

difficulty and other preferences of the learners. The definition and representation of these abstract training scenarios was based on a specific instructional ontology that takes into account related standards and overcomes their shortcomings.

- Adaptation model: The adaptation process is encapsulated in an appropriate personalization algorithm that exploits information from the Learner model to firstly select appropriate abstract training scenarios matching Learner's needs and preferences and proceeds with the binding of appropriate reusable Learning Objects to the learning activities of the selected scenario. The same mechanism can be used to construct assessment tests from assessment objects that can be used for the identification of the previous knowledge of the Learner.

Chapter 4. ARCHITECTURE

4.1. Introduction

In this chapter, an integrated service-oriented architecture is proposed based on the model presented, meeting the user requirements and addressing the interoperability problems described in Chapter 2. The functional components of this architecture are described, as well as their functionality and services. The architecture exploits widely-accepted standards and protocols and integrates repositories, tools and other components to support access, use and re-purposing of the cultural digital content residing in cultural heritage institutions for the development of learning experiences to support different learning needs and contexts. Integral part of this architectures are components to support the development of pedagogically-driven personalized learning experiences statically or dynamically, as they have been modeled and described in the previous chapter.

4.2. Architecture

To meet the user requirements set in Chapter 1, this architecture supports the following functional requirements:

- Support the gradual development of learning experiences from cultural digital objects allowing the creation, management, access, use and reuse of defined objects at all levels through appropriate repositories, tools, services and standards.

- Provide tools for the creation of educational templates to guide the creation of pedagogically-sound learning experiences.

- Provide components to support the dynamic creation of pedagogy-driven personalized learning experiences, which can be exploited both by courseware authors and learners, as presented in Chapter 3.

- Support interoperability and sharing of cultural digital objects, learning objects and learning experiences with existing eLearning systems and large repositories/aggregators.

The architecture illustrated in Figure 4.1 consists of layered repositories and tools supporting the gradual creation of learning experiences starting from existing cultural digital content residing at digital archives and the creation of pedagogy-driven personalized learning experiences in a static or dynamic way as already described. The architecture is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification [IMS DRI, 2003] introduced in Chapter 2 providing 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.

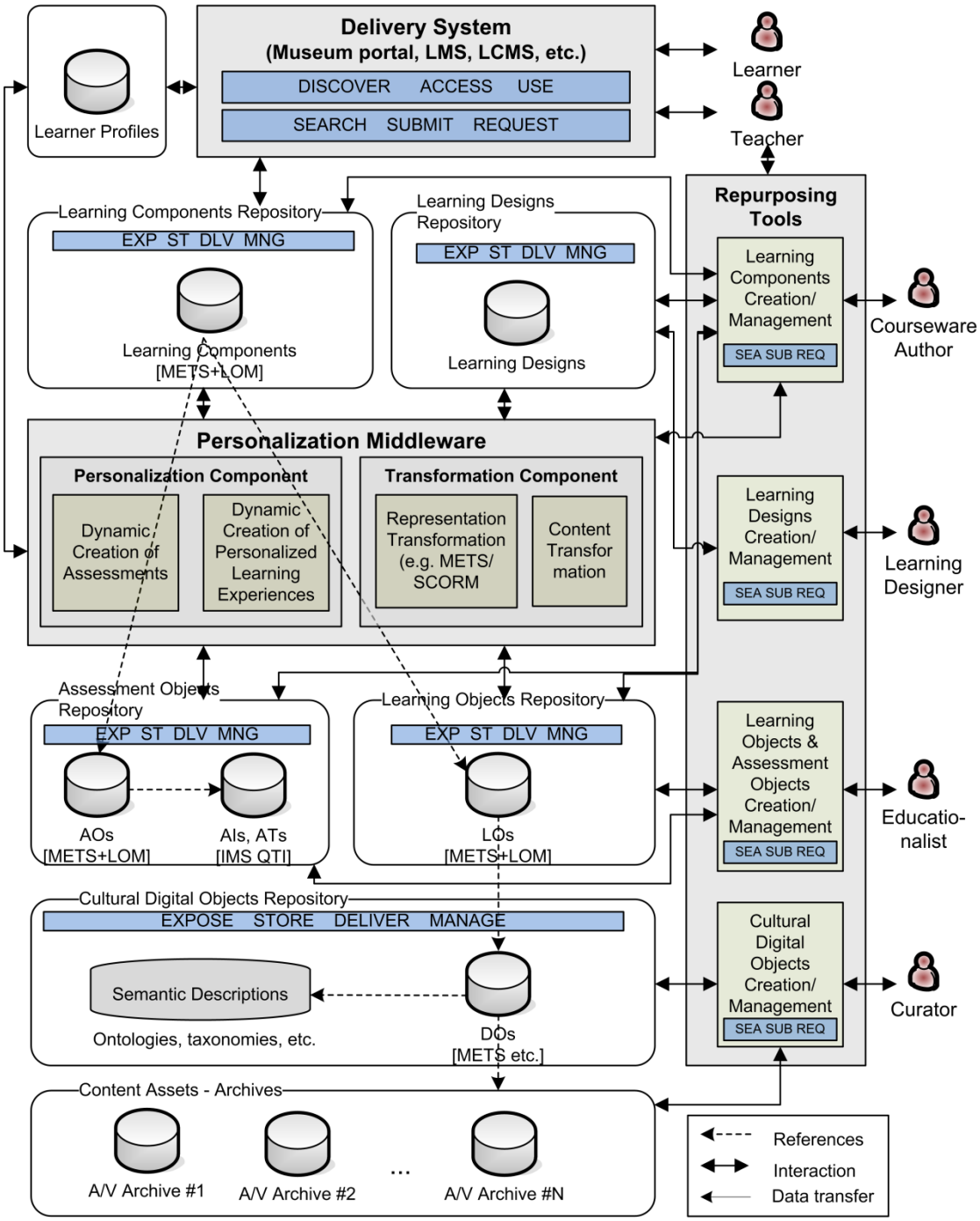

Figure 4.1 The architecture

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
- Intermediares: Services that reside between the above two (e.g. aggregators, brokers)

Figure 4.1 illustrates the architecture components, which are the following:

- Appropriate **repositories and services** for the management of the objects according to the domain model described in Chapter 3: Content Assets, Cultural Digital Objects (CDOs), Learning Objects (LOs), Assessment Objects (AOs) and Learning Components (LCs).
- **Repurposing tools** for the creation and editing of the above types of objects as well as for the creation of abstract training scenarios (Learning Designs) according to the instructional model presented in order to support the creation of pedagogically-sound personalized learning experiences.
- The **Personalization Middleware**, responsible for the dynamic creation of personalized learning experiences and assessment tests and their transformation to SCORM format to be delivered to eLearning applications based on the adaptation model presented. The middleware consists of:
    - The **Personalization Component** used for the **Dynamic Creation of Personalized Learning Experiences** according to specific learning needs expressed in **Learner Profiles** (including the concepts of the Learner model presented) and using a set of abstract training scenarios (**Learning Designs**). The Personalization Component also 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).
- **Delivery system** (Software Agents in terms of IMS DRI, e.g., museum portals, Learning (Content) Learning Management Systems etc.) that discover, access and use the content of the digital library through appropriate services (resource utilizers). Learning Management Systems in this framework include components encapsulating functionality to track user's progress and update the user related information represented in Learner Profiles.

4.2.1. Repositories

According to the framework of this thesis, the specification of the services offered by this architecture 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. <u>These functions are not considered in Phase 1 of the DRI specification</u>.

The services for the management of objects in DO, LO, AO and LC repositories are presented in Table 4.1 categorized according to IMS DRI and are described in detail in the following subsections.

Table 4.1 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 createOfFinal_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
Gather/ Expose	Implementation of the OAI-PMH harvesting protocol.			

4.2.1.1. 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.

4.2.1.1.1 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.

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.
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.

Service output:

Parameter name	Parameter type	Description
search_DOReturn	Vector	An array containing the DOids of the DOs that satisfy the query parameters.

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.

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. 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>

4.2.1.1.2 Submit/Store

checkin_Description

This service creates or updates a description

Service input:

Parameter name	Parameter type	Description
incomingDesc	Document	Corresponds to an XML document that contains the XML representation of the new Description.

Service output: none

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.

checkout_Description

This service loads an existing description from the DO repository.

Service input:

Parameter name	Parameter type	Description
DescId	string	The DescId of the description that should be loaded

Service output:

Parameter name	Parameter type	Description
descReturn	Document	An XML document containing the description

get_DescriptionList

This service returns the list of descriptions.

No Service input:

Service output :

Parameter name	Parameter type	Description
descriptionList	String	An XML document containing title and Id couples for all available descriptions

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.

4.2.1.1.3 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 wants 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 be 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.

4.2.1.1.4 Gather/Expose

For the gather/expose function, the implementation of OAI-PMH harvesting protocol is recommended by IMS DRI. Depending on the aggregator/harvester the OAI-PMH on target repositories should be implemented accordingly in terms of the metadata scheme(s) used. For example, if we intend to expose the Cultural Digital Objects metadata to Europeana, then appropriate transformations should be made to transform the metadata to ESE schema (if the Cultural Digital Objects are not already described according to this schema).

4.2.1.2. 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. 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.

4.2.1.2.1 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.

Service input:

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.
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.
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.

Service output:

Parameter name	Parameter type	Description
search_LOReturn	Vector	An array containing the LOids of the LOs that satisfy the given filters.

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_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.

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 LOs.
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.
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 depends on the ontology representation format (e.g. cogxml).

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.

4.2.1.2.2 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.

Service input:

Parameter name	Parameter type	Description
incomingDoc	Document	It corresponds to an XML document with the representation of the new LO using METS.

Service output:

Parameter name	Parameter type	Description
create_LOReturn	string	A string representing 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.

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.

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.

4.2.1.2.3 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 it 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.

4.2.1.2.4 Gather/Expose

For the gather/expose function, the implementation of OAI-PMH harvesting protocol is recommended by IMS DRI. Depending on the aggregator/harvester the OAI-PMH on target repositories should be implemented accordingly in terms of the metadata scheme(s) used. For example, if we intend to expose the Learning Objects' metadata to ARIADNE, then the "transferred" metadata harvested by ARIADNE should conform to its LOM Application Profile.

4.2.1.3. 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. 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.

4.2.1.3.1 Search/Expose

search_AO

This service is used in order to search for AOs satisfying a given Boolean LOM filter.

Service input:

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.
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.
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.

4.2.1.3.2 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.
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.
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.

4.2.1.3.3 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 it 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.

Service output:

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.

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.

4.2.1.3.4 Gather/Expose

For the gather/expose function, the implementation of OAI-PMH harvesting protocol is recommended by IMS DRI. Depending on the aggregator/harvester the OAI-PMH on target repositories should be implemented accordingly in terms of the metadata scheme(s) used. For example, if we intend to expose the Assessment Objects' metadata to ARIADNE, then the "transferred" metadata harvested by ARIADNE should conform to its LOM Application Profile.

4.2.1.4. Learning Components Repository services

This section presents the services offered by the Learning Components Repository Before proceeding with the description of the services it should be noted that the state (EDITING or RENDERED) of LCs is represented using the lifecycle/status LOM element. In particular the 'draft' value of this element is used to represent a LC that is in EDITING state while the 'final' value is used to represent a LC that is in RENDERED state.

4.2.1.4.1 Search/Expose

search_LC

This service is used in order to search for LCs 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 LC. 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 LCs. If the flag is false, then only the LC metadata is considered and only LCs with LOM metadata matching the filter is returned. If the flag is true, then additional LCs are returned: those that have LOs with metadata matching the filter even if the LC LOM metadata do not match the filter.

Service input:

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 LCs.
checkLOs	boolean	A Boolean flag. If it is true the filter is applied to LOs and any LC that contains any of the qualifying LOs is also returned by the service.

Service output:

Parameter name	Parameter type	Description
search_LCReturn	Vector	An array containing the LCids of the LCs 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_LC

This service is used in order to search for LCs satisfying a given Fuzzy LOM filter. The result is a ranked list of the qualifying LCs. 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 LCs. If the checkLOs flag is false, then only the LC metadata is considered and the ranks are computed by matching the Fuzzy LOM filter with the LC metadata. If the checkLOs flag is true, then the final rank is computed by combining the rank of the LC (as computed using only the LC LOM metadata) and the ranks of the LOs inside the LC (as computed using only the LO LOM metadata).
The formula to combine the ranks is the following:
Final rank = $a_1 * r + a_2 * (r_1 + r_2 + \ldots + r_n) / n$

Where a1 and a2 are two real values that add to one (a1+a2 = 1) representing the relative importance of the rank given to the LC without considering its LOs (r) and the ranks given to its LOs (r1, r2, …, rn). The number of LOs inside the LC 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 LCs.
checkLOs	boolean	A Boolean flag. If it is true the filter is also applied to LOs and the final rank for the LC is computed by combining the ranks of the LOs inside a LC and the rank of the LC.
weight	float	This parameter essentially corresponds to parameter a1 given in the formula above combining the rank of the qualifying LC and the ranks of its LOs. a2 in the same formula is computed as a2=1-weight.

Service output:

Parameter name	Parameter type	Description
fuzzy_search_LCReturn	Vector	An array containing the <LCid,rank> pairs of the LCs that satisfy the given filter and the corresponding ranking of each LC.

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.

4.2.1.4.2 Submit/Store

create_LC

This service creates a new LC and gives a new LCid to it that is returned by the service. The new LC is set in EDITING state by default. Creating LC involves submission and storage of the LC description (METS document) to the LC 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.

Service output:

Parameter name	Parameter type	Description
create_LCReturn	string	A string representing the unique LCid given to the newly created LC.

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_LC

This service updates an existing LC. The LC should be in EDITING state in order to be updated. If the LC is in RENDERED state, no update is made and an appropriate error message is returned. Updating a LC involves submission and storage of the new LC description (METS document) to the LC repository.

Service input:

Parameter name	**Parameter type**	**Description**
LCid	string	The LCid of the LC that should be updated.
newDoc	string	It corresponds to an XML document with the representation of the new AO using METS.

Service output:

Parameter name	**Parameter type**	**Description**
update_LCReturn	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_LC

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

Service input:

Parameter name	**Parameter type**	**Description**
LCid	string	The LCid of the LC that should be deleted.

Service output:

Parameter name	**Parameter type**	**Description**
delete_LCReturn	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_LC

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

Service input:

Parameter name	**Parameter type**	**Description**
LCid	string	The LCid of the LC that should be put in RENDERED state.

Service output:

Parameter name	Parameter type	Description
render_LCReturn	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_LC

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

Service input:

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

Service output:

Parameter name	Parameter type	Description
createCopyOfRendered_LCReturn	string	This string contains the unique LCid given to the newly created LC.

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.

4.2.1.4.3 Request/Deliver

get_LC

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

Service input:

Parameter name	Parameter type	Description
LCid	string	The LCid of the LC to be retrieved.

Service output:

Parameter name	Parameter type	Description
get_LCReturn	string	The METS document in the form of a string that corresponds to the description of the LC 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_LC

Get all LOids of the LOs that are contained in a specific LC. The descriptions of these LOs can be later retrieved using the corresponding services of the LO repository.

Service input:

Parameter name	Parameter type	Description
LCid	string	The LCid of the LC for which the constituent LOs are requested.

Service output:

Parameter name	Parameter type	Description
get_All_LO_in_LCReturn	Vector	An array containing the LOids of the LOs that are contained in the LC whose LCid 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_LC_summary

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

Service input:

Parameter name	Parameter type	Description
LCids	Vector	The LCids of the LCs 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 LCs specified in the first parameter.

Service output:

Parameter name	Parameter type	Description
get_LC_summaryReturn	Vector	An array containing the requested metadata elements for each one of the specified LCs. Each entry in this array is another array (Vector) that contains the LCid of a LC 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.

4.2.1.4.4 Gather/Expose

For the gather/expose function, the implementation of OAI-PMH harvesting protocol is recommended by IMS DRI. Depending on the aggregator/harvester the OAI-PMH on

target repositories should be implemented accordingly in terms of the metadata scheme(s) used. For example, if we intend to expose the Learning Components' metadata to ARIADNE, then the "transferred" metadata harvested by ARIADNE should conform to its LOM Application Profile.

4.2.2. Authoring/repurposing tools

This section describes the functionality offered to the users of the authoring environment, to support the authoring process described in Chapter 3 giving a user-centric description of the tools.

4.2.2.1. Creation and management of Cultural Digital Objects

The tool for the creation of Digital Objects allows for the selection of Content Assets and the creation of metadata annotations for them (or parts of them). The creation and editing of Digital Objects is presented in Figure 4.2.

The first step in the process of Digital Objects creation/editing is to create a new description or load an existing one. In order to create a new description the user has to select the indexing type (image, video, text etc.), then select the corresponding Content Asset and finally select one of the available ontologies, taxonomies or vocabularies to be used for semantic annotations.

As soon as the user has created a description or loaded an existing one, (s)he may iteratively do several editing actions depending on the indexing type:

- For images, the user is able to define the spatial scope of annotations, i.e. specify spatial regions inside the initial image that correspond to image segments. Then for each such segment the user is able to define administrative metadata and semantic metadata.

- For video and audio, the user is able to define the temporal scope of annotations, i.e. specify temporal regions inside the initial video/audio that correspond to visual/audio segments. Then, for each such segment the user is able to define administrative metadata and semantic metadata.

- For other media annotations (e.g. text), the selected content asset is handled as a whole. The user is able to define administrative metadata and semantic metadata for it.

After all editing actions have been performed the user may save the description created and close it.

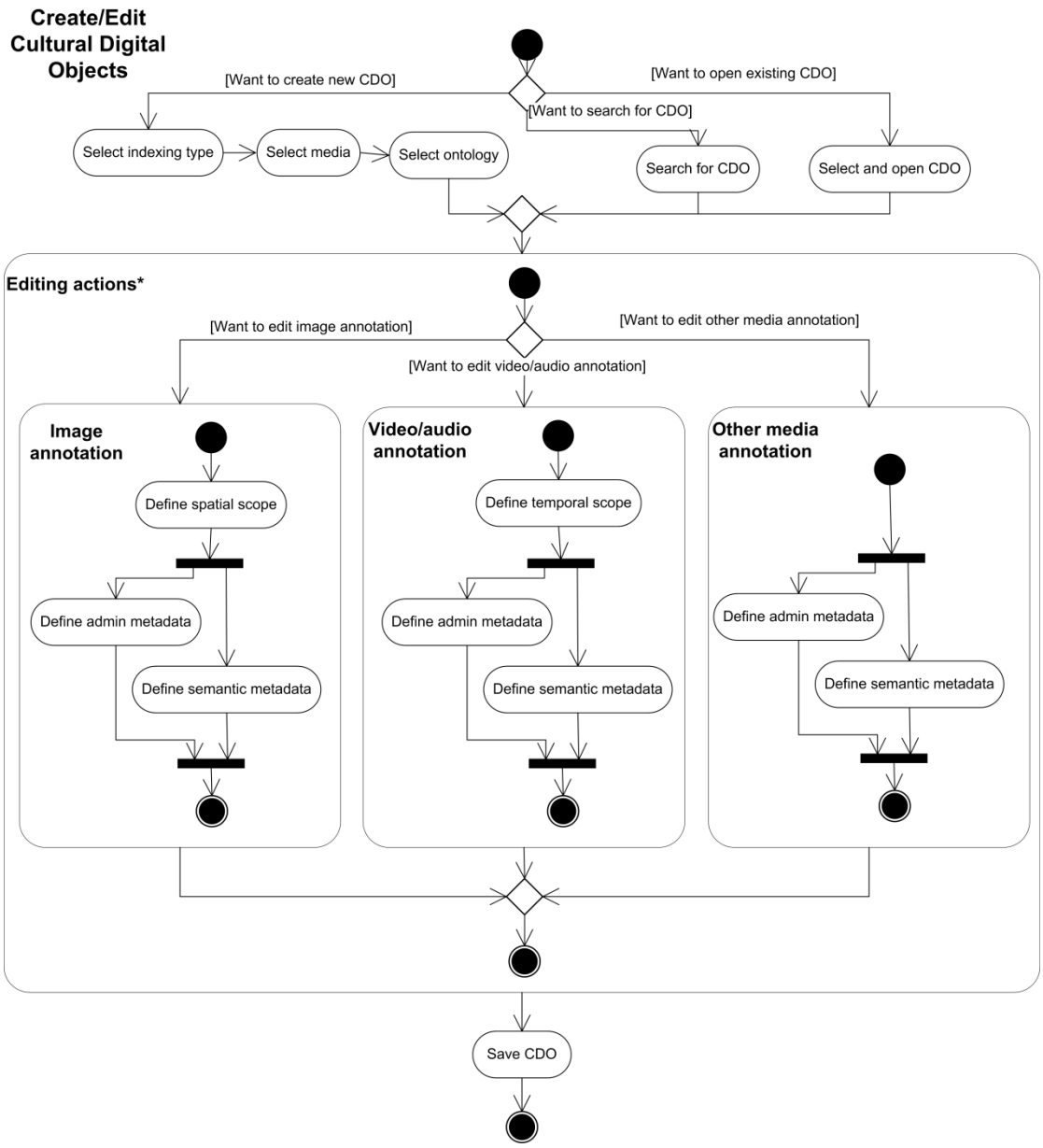

Figure 4.2 Creation and editing of Cultural Digital Objects

4.2.2.2. Creation and management of Learning Objects

The tool for the creation and management of Learning Objects allows for the selection of Digital Objects to create Learning Objects and the definition of educational metadata for them following the LOM standard. The creation and editing of Learning Objects is presented in the following activity diagram of Figure 4.3.

The first step in the process is to create a new Learning Object or open an existing one for further editing. Alternatively, the user can search for a particular Learning Object using various search parameters defined over the LOM metadata of the Learning Objects.

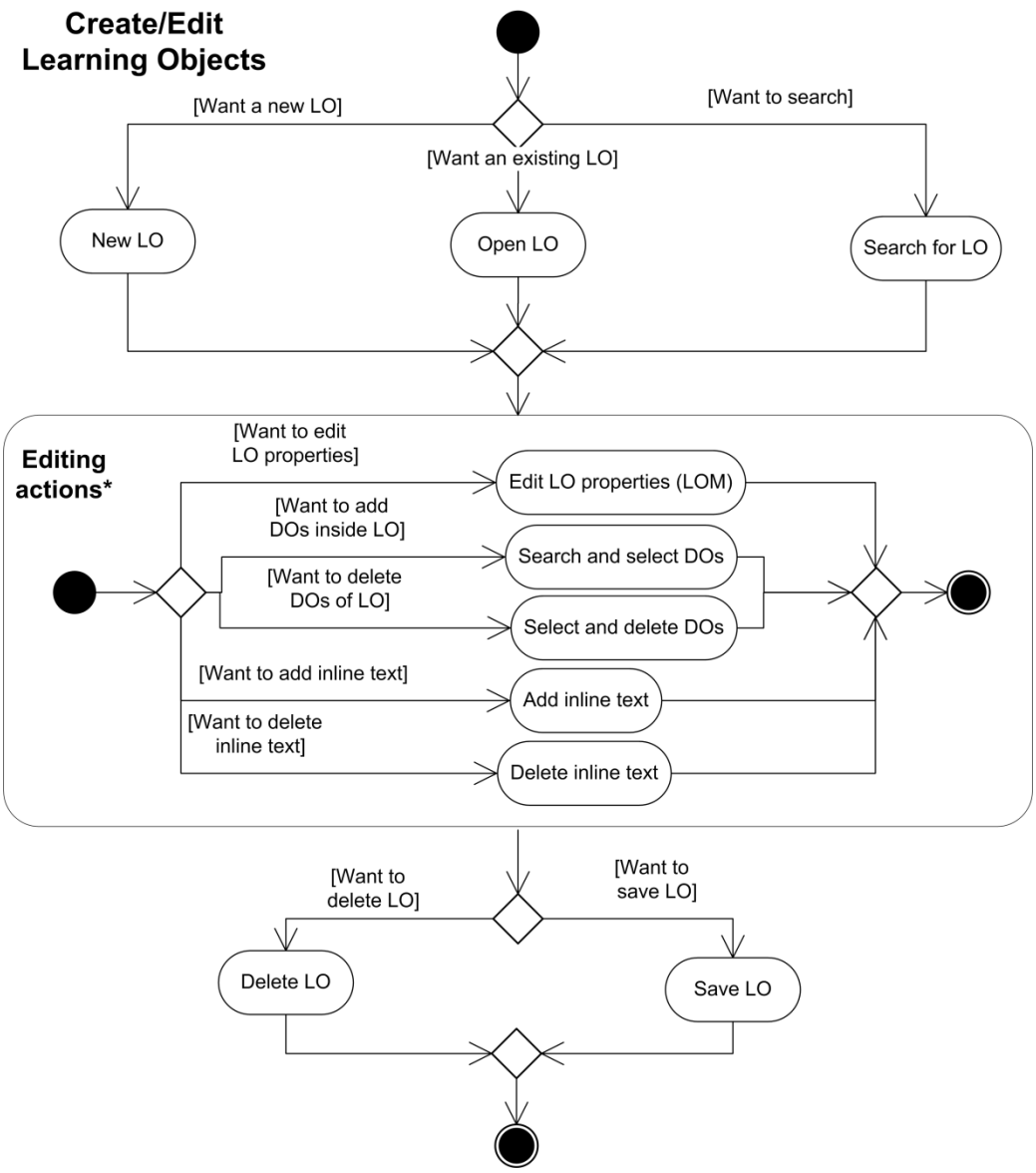

Figure 4.3 Creation and editing of Learning Objects

As soon as the user has created or selected/opened an existing Learning Object, (s)he is able to do iteratively the following editing actions:

- Edit the LOM properties of the Learning Object, i.e. specify the values of the various LOM metadata elements. These elements are the standard elements defined by LOM such as title, language, textual description, keywords contributors etc. Some of the LOM metadata elements will be automatically computed using the metadata of the Digital Objects that are contained in the Learning Object. Such metadata mainly refer to technical information (format, size etc.).

- Search for Digital Objects and select some of them in order to be included in the currently edited Learning Object. Each Learning Object contains a collection of

Digital Objects that represent the material necessary to accomplish a certain educational goal (the Learning Objective of the Learning Object).

- Browse the Digital Objects associated with the edited Learning Object and possibly select and delete some of them.
- Add or delete inline text between Digital Objects.

After finishing the editing work the user is able to save the created/updated Learning Object. (S)he can also delete existing Learning Objects.

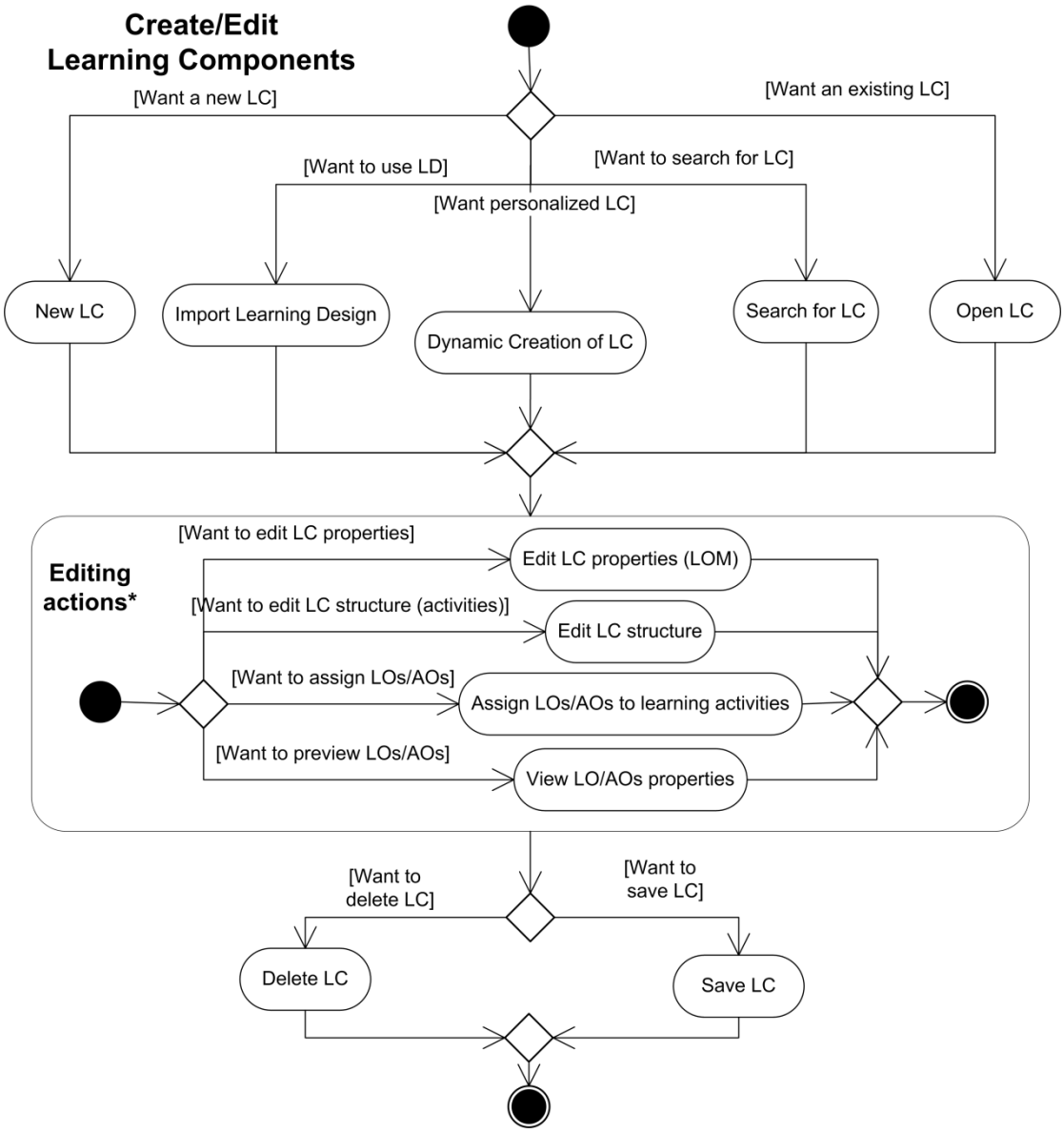

Figure 4.4 Creation and editing of Learning Components

4.2.2.3. Creation and management of Learning Components

The tool for the creation and management of Learning Objects allows for the selection of Learning/Assessment Objects to create Learning Components and the definition of

educational metadata for them following the LOM standard. The creation and editing of Learning Components is presented in the activity diagram of Figure 4.4.

4.2.2.4. Creation and management of Learning Designs

The tool for the creation and management of Learning Designs has the following functionality:

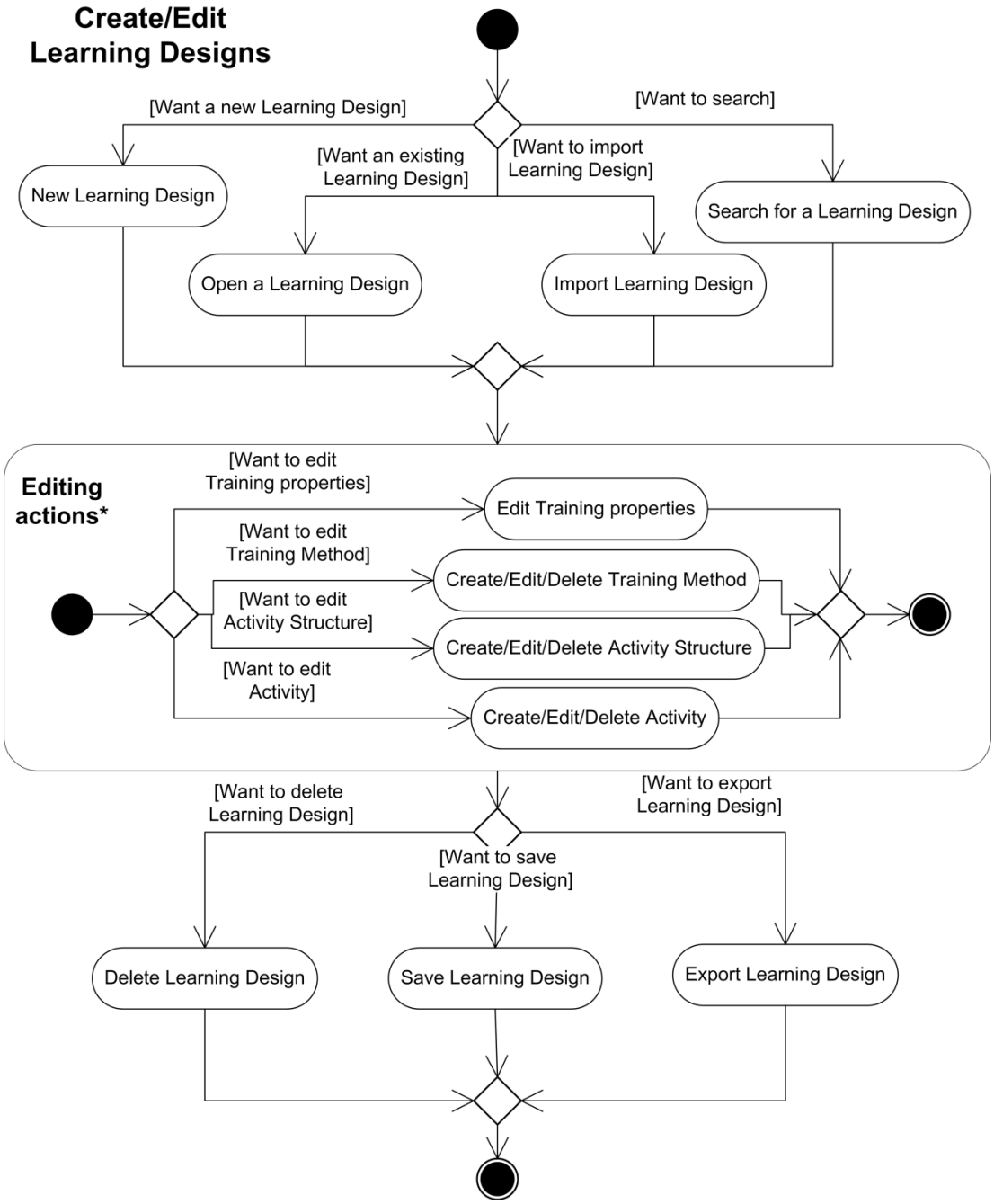

Figure 4.5 Creation and Editing of Learning Designs

- 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, Training Methods, Activity Structures, Activities and preferred Learning Object Types signifying appropriate types of learning objects depending on the target Learner Profile

- 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 Figure 4.5.

4.2.3. Personalization Component

The dynamic creation of personalized learning experiences described in Chapter 3 is done by the Personalization Component cooperating with a number of other components of the architecture. The **Personalization Component** 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, which is delivered through the e-learning application (e.g. the LMS 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.

In the **Dynamic Creation of Assessments**, the Personalization Component follows a similar procedure to this 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.

The process and algorithm for the Dynamic Creation of Personalized Learning Experiences and Assessments have been described in detail in Chapter 3.

4.2.4. Transformation Component

The intermediate format of the learning experience generated as a result of the personalization process described in Chapter 3 is transformed by the Transformation Component to an appropriate format and delivered to the Learner. Figure 4.6 illustrates how the intermediate format is transformed to METS.

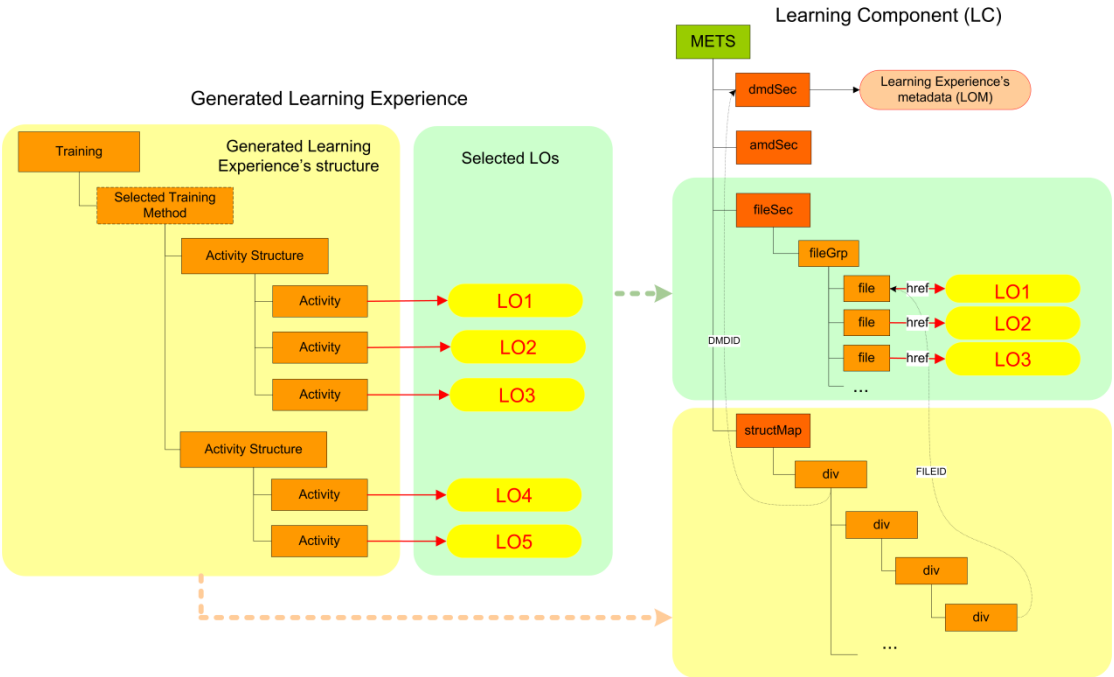

Figure 4.6 Transformation of the intermediate format of the learning experience to the final format (in this case METS)

The METS representation can be further transformed to SCORM. In Figure 4.7 and Table 4.5 the mapping between METS and SCORM IMS Manifest is given.

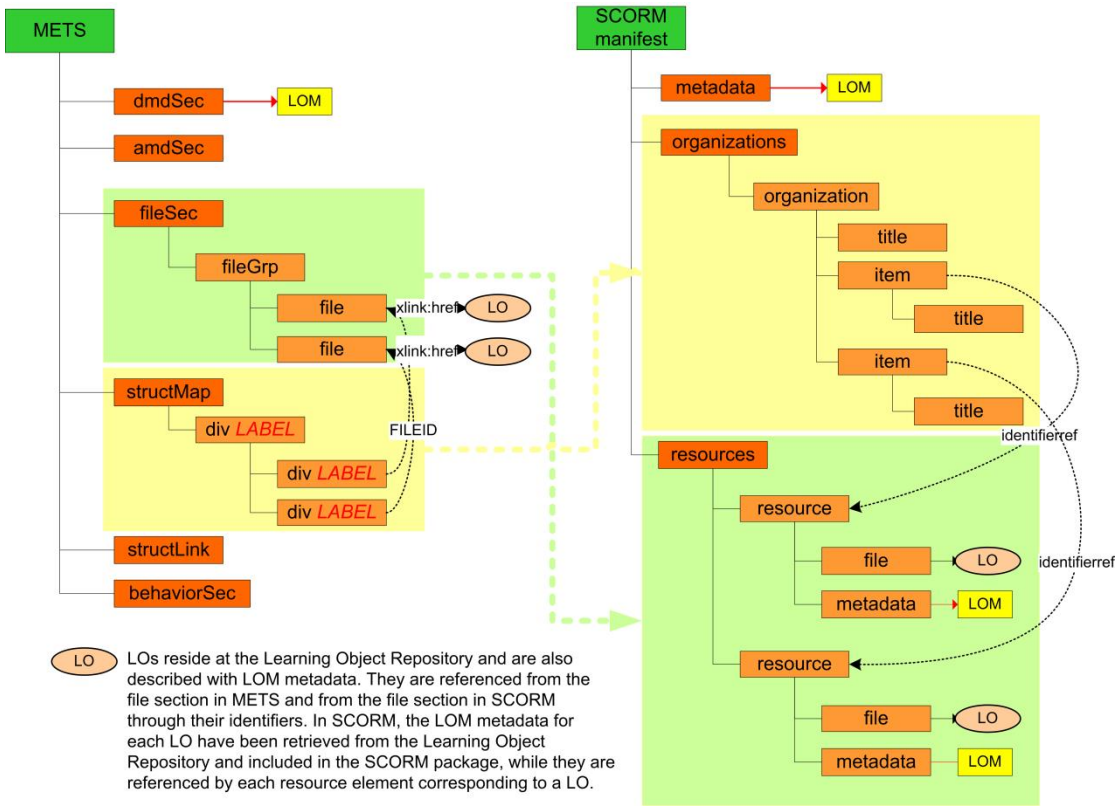

Figure 4.7 Mapping of the METS-based representation of the Learning Component to a SCORM learning experience in order to be delivered to eLearning Applications

Table 4.2 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.

The process of transformation of METS-based representation of a Learning Component to a SCORM package includes four main steps, as illustrated in Figure 4.8:

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)

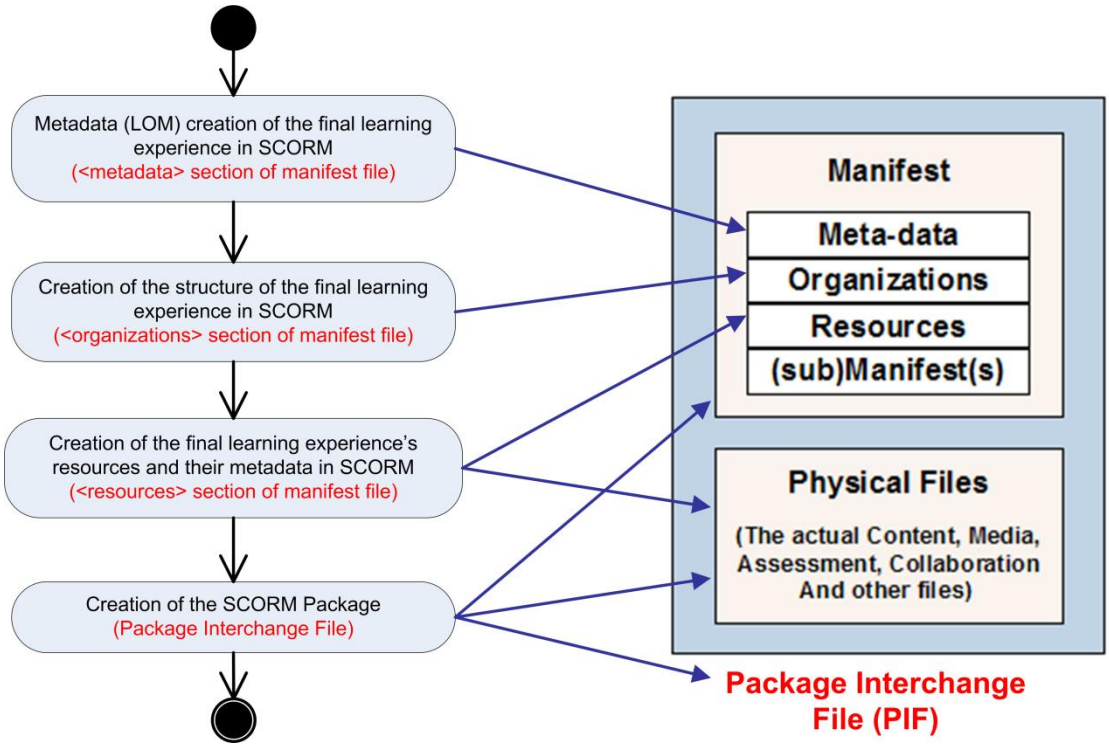

Figure 4.8 Overall process of generation of a SCORM package from a courseware object

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 4.9).

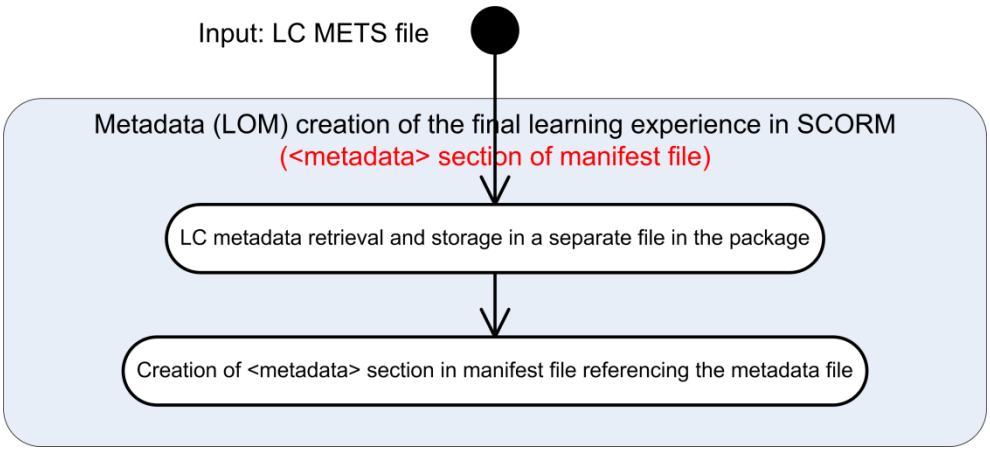

Figure 4.9 Creation of metadata of the final learning experience in SCORM (metadata section of manifest file)

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 4.10.

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.

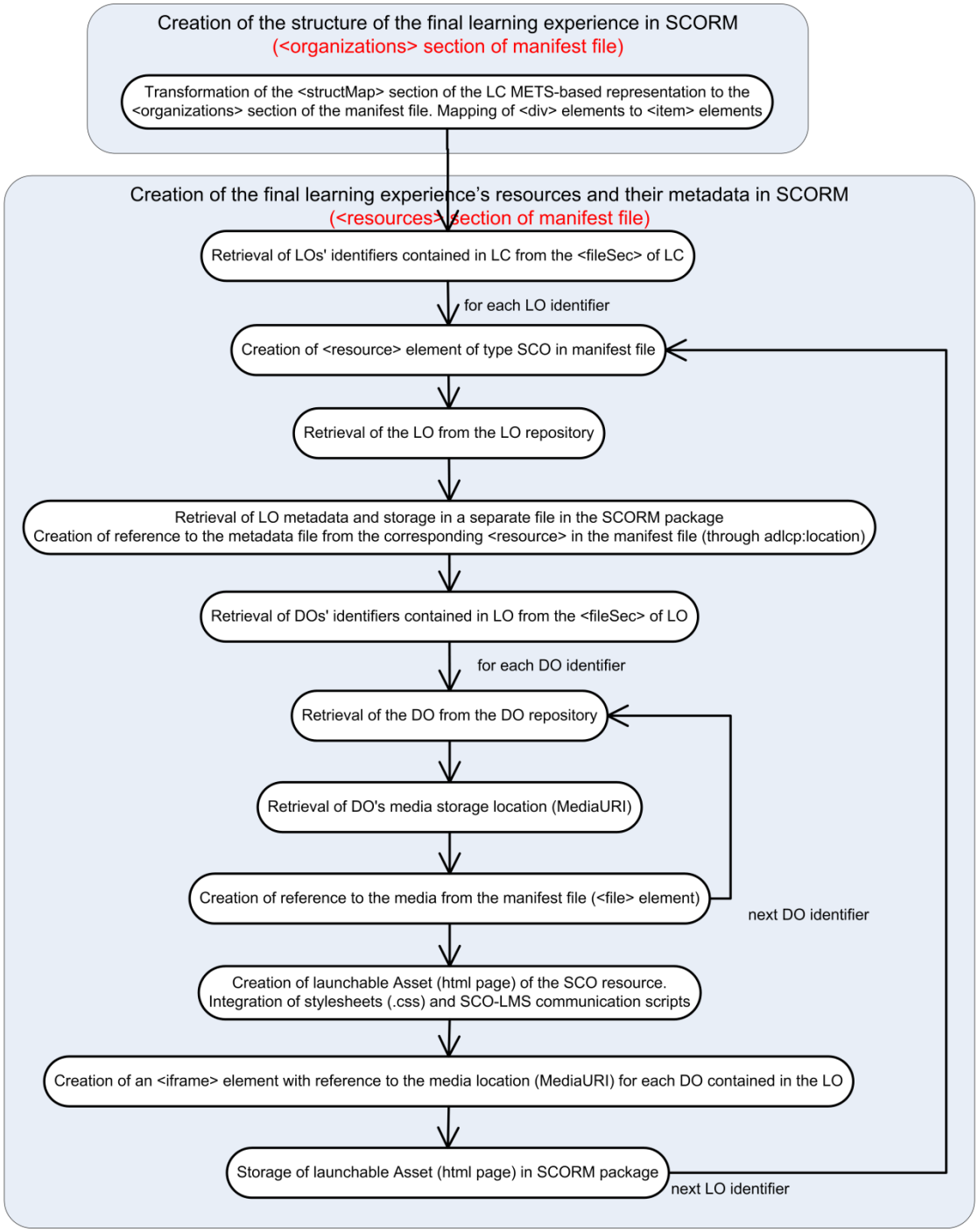

Figure 4.10 Creation of the structure of the final learning experience (organizations section of manifest file) and the learning experience's resources and their metadata (resources section of manifest file)

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 4.3). 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 4.3 Example 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&amp;fid=824"
width="800" height="100%">
          <a
href="http://212.92.2.161/mediaserver/getfile.php?type=document&amp;fid=824"
>Hmm, you are using a very old browser.Click here to go directly to included
content.</a>
        </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&amp;fid=905"
width="800" height="100%">
          <a
href="http://212.92.2.161/mediaserver/getfile.php?type=document&amp;fid=905"
>Hmm, you are using a very old browser.Click here to go directly to included
content.</a>
        </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&amp;fid=925"
width="800" height="100%">
          <a
href="http://212.92.2.161/mediaserver/getfile.php?type=document&amp;fid=925"
>Hmm, you are using a very old browser.Click here to go directly to included
content.</a>
        </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 rhythmics. 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.

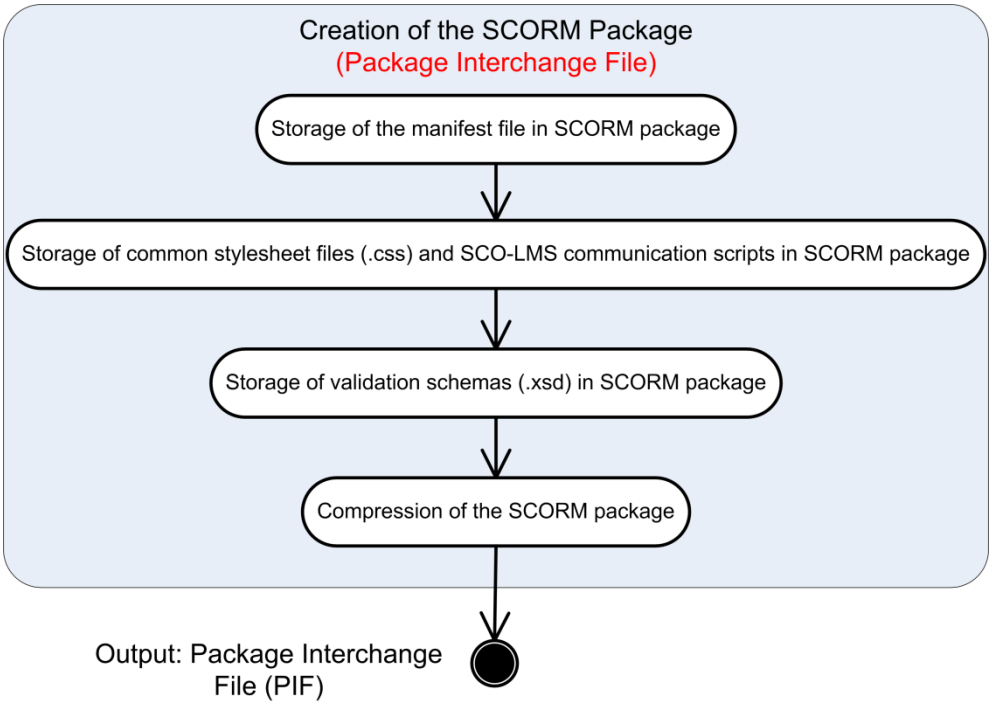

Figure 4.11 Creation of the final SCORM Package (Package Interchange File - PIF)

4.3. Summary

In this chapter, the functional requirements to support the user requirements and the model presented in Chapter 3 have been defined and an integrated service-oriented architecture was presented to support access, use and re-purposing of the cultural digital content residing in cultural heritage institutions for the development of learning experiences and the creation of pedagogically-driven personalized learning experiences statically or dynamically, as they have been modelled and described in Chapter 2.

Towards this end, the architecture integrates: 1) **Repositories and services** for the management of Content Assets, Cultural Digital Objects (CDOs), Learning Objects (LOs), Assessment Objects (AOs) and Learning Components (LCs), 2) **Repurposing tools** for the creation and editing of the above types of objects as well as for the creation of abstract training scenarios (Learning Designs) according to the instructional model presented in order to support the creation of pedagogically-sound personalized learning experiences, and 3) Components for the dynamic creation of personalized learning experiences and assessment tests (**Personalization Component**) and their transformation to SCORM format to be delivered to eLearning applications (**Transformation Component**).

The architecture adopts widely-accepted standards and protocols for repositories interoperability following the recommendations of IMS DRI in addition to the standards for the description, structuring and packaging of the objects at all levels as proposed in this framework and presented in Chapter 3.

Chapter 5. IMPLEMENTATION AND APPLICATION OF THE PROPOSED FRAMEWORK AND ARCHITECTURE

5.1. Introduction

Part of the research was made and implemented in LOGOS and Natural Europe projects. Continuation of implementation and application of the PhD research is done as a series of papers published under the support of Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018), funded by the Bulgarian Sciences Fund.

5.2. LOGOS project

The framework and architecture presented in this thesis was implemented in LOGOS project "Knowledge-on-Demand for Ubiquitous Learning" (IST-4-027451) (common project with IMI-BAS), where a Knowledge-on-Demand ubiquitous learning platform was developed, 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 framework and architecture proposed were applied and implemented to support the needs of repurposing of existing multimedia material and the gradual development of pedagogy-driven personalized learning experiences in a static or dynamic way [Arapi, Moumoutzis, Mylonakis, Theodorakis, and Stylianakis, 2007; Arapi, Moumoutzis, Mylonakis, Stylianakis, Theodorakis, and Christodoulakis, 2008].

The primary target group of the projects are the eLearning actors (authors of courses, lecturers, advanced learners, learning content providers) creating courseware materials for university students and/or for adult learners in non-formal and informal education. The secondary target group consists of eLearning providers (companies and training institutions) and technology providers (DTV-companies, mobile operators), interested of cross-media delivery of learning materials.

5.2.1. LOGOS architecture

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 depicted in Figure 5.1 [Arapi, Moumoutzis, Mylonakis, Theodorakis, and Stylianakis, 2007; Arapi, Moumoutzis, Mylonakis, Stylianakis, Theodorakis, and Christodoulakis, 2008; Moumoutzis, Arapi, and Stockinger, 2008] integrates:

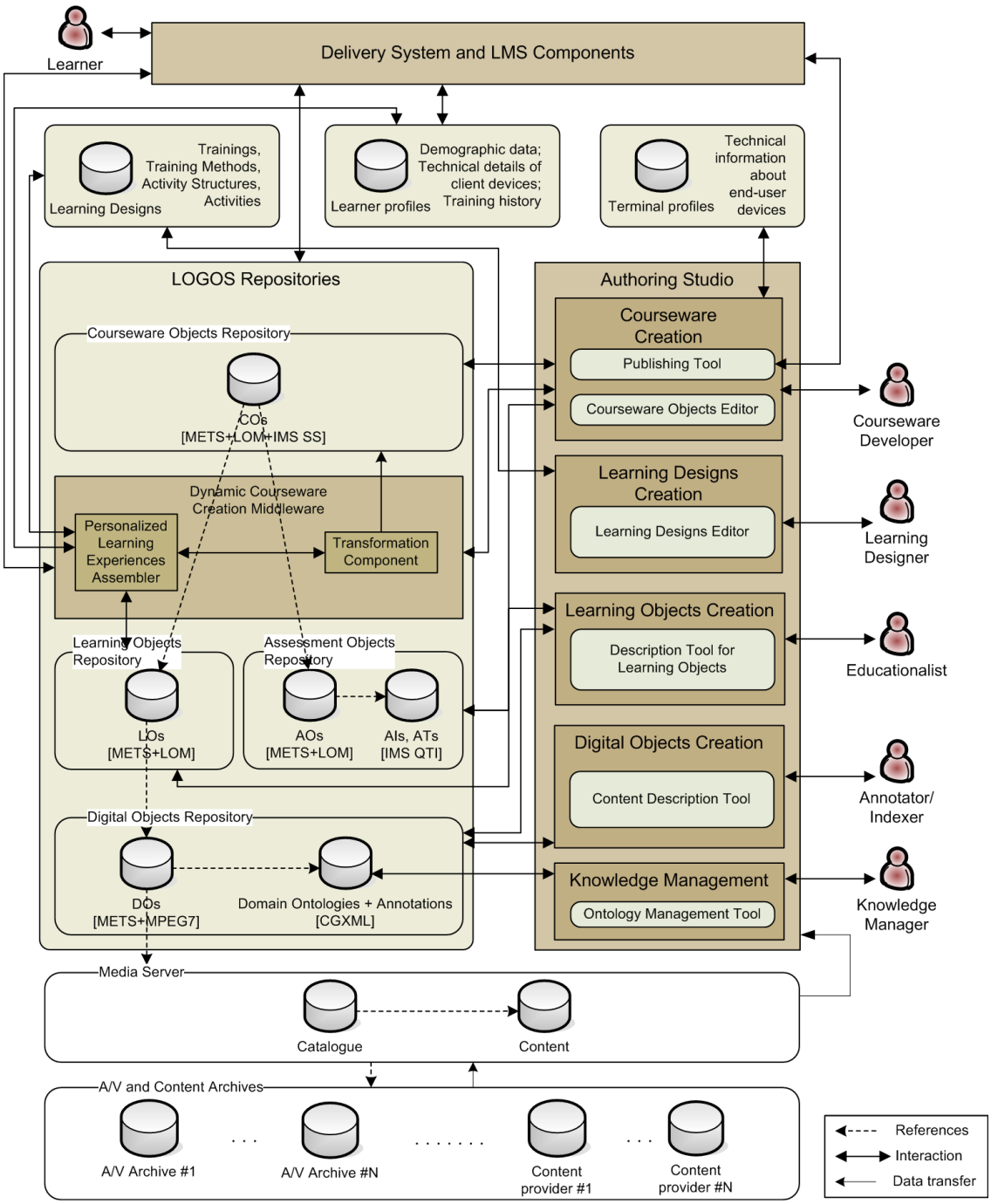

Figure 5.1 LOGOS project overall architecture

- **Repositories and services** for the management of LOGOS objects: Media Objects (MOs), Digital Objects (DOs), Learning Objects (LOs), Audiovisual Objects (AOs) and Courseware Objects (COs).

- 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 **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.

- **Learning Management System components** for the delivery of courseware/learning experiences 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.

5.2.2. LOGOS objects/repositories

LOGOS follows a hierarchical approach in the categorization of the objects it manages, and their representation is based on the framework presented in this thesis.

Appropriate repositories and services for the management of various types of objects:

- **Media Objects (MOs)** coming from external content archives,

- **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,

- **Learning Objects (LOs)** built on top of Digital Objects and enriched with learning metadata.

- **Assessment Objects (AOs)** 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) and are enriched with learning metadata.

- **Courseware Objects (COs)** 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 by LOs or AOs and they are described with educational metadata and possibly sequencing and navigation metadata.

The following figure illustrates the relation among COs, LOs, AOs, DOs and Media Objects:

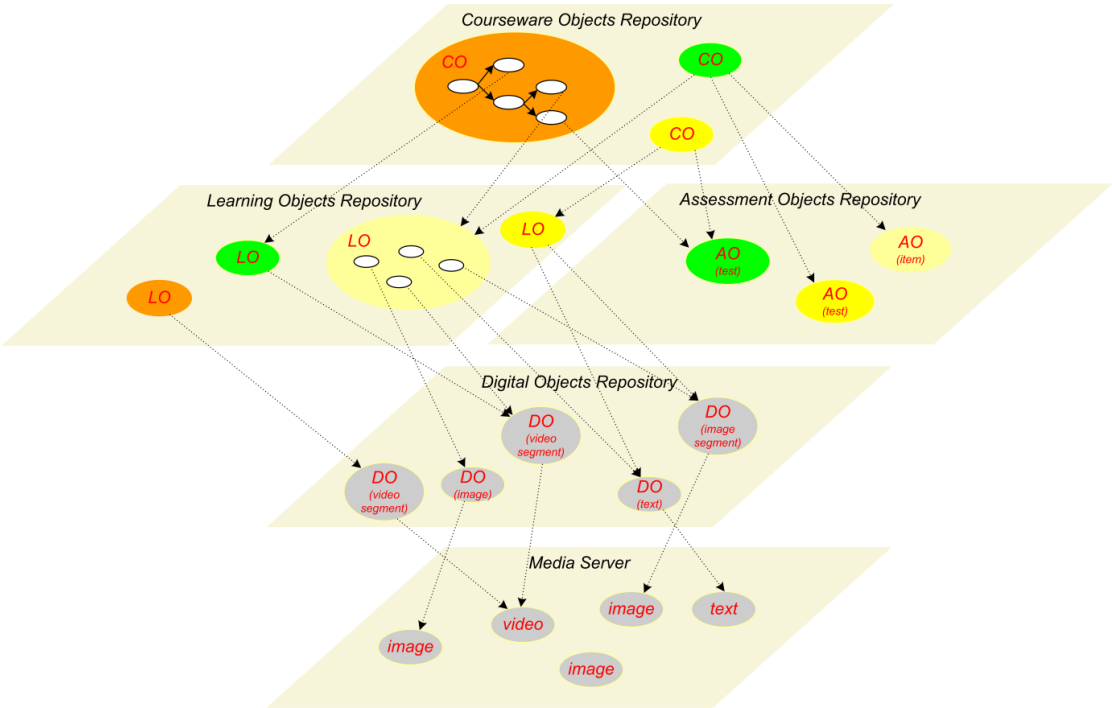

Figure 5.2 Relation among COs, LOs, AOs, DOs and Media Objects residing in corresponding repositories and the Media Server

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

- 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 CoGXML[5] (a representation format for conceptual graphs) and the administrative metadata section (amdSec) in order to incorporate administrative metadata expressed in MPEG7. The 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.

[5] http://cogitant.sourceforge.net/cogitant_html/cogxml.html

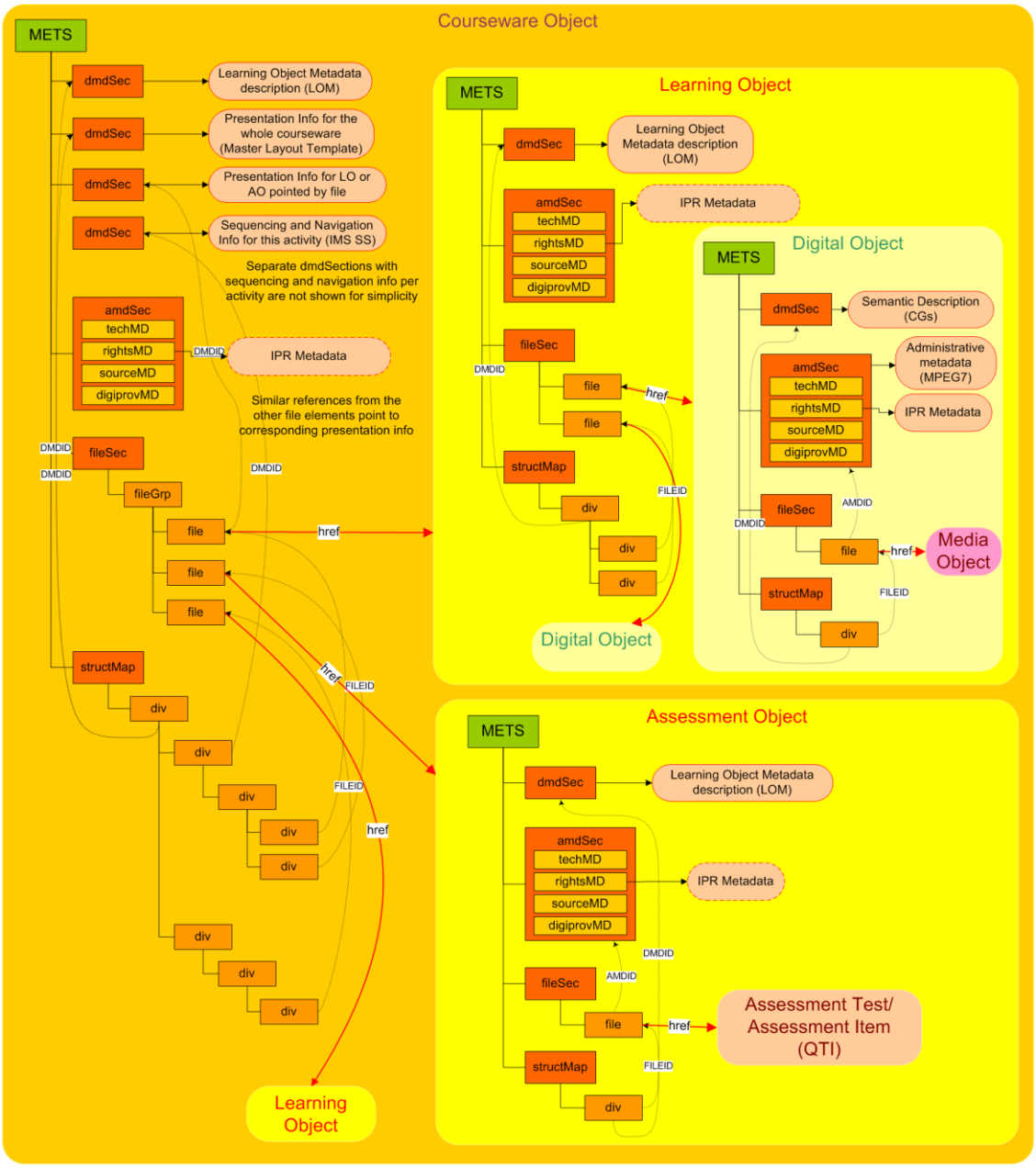

Figure 5.3 COs, LOs, AOs, DOs, MOs and their relations using METS according to the interoperability framework

- 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.

The LOM metadata that are used for the educational description of LOs, AOs and COs include all needed pedagogical information as proposed in this thesis to support the personalization process.

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 this thesis and defined in Chapter 4 (Section 4.2.1). In the scope of LOGOS project services to support the following functions were implemented: Search/Expose, Submit/Store, Request/Deliver and Alert/Expose. Table 5.1 summarizes the services implemented for the management of objects in DO, LO, AO and CO repositories. Their detailed implementation is presented in [Moumoutzis, Arapi, and Stockinger, 2008; Stylianakis, 2008].

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

5.2.3. LOGOS Tools – The LOGOS Authoring Studio

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 **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.

- 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.

5.2.3.1. The Learning Designs Editor

A special tool has been implemented for the creation and management of Learning Designs that are based on the instructional model and the functional specifications presented in Chapters 3 and 4 along with an underlying repository and appropriate web services [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 5.4). The constructed Learning Designs are stored in a special repository providing appropriate services for their access and management.

Specifically, the architecture for the creation of learning designs consists of the following layers [Theodorakis, 2007]:

- 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.

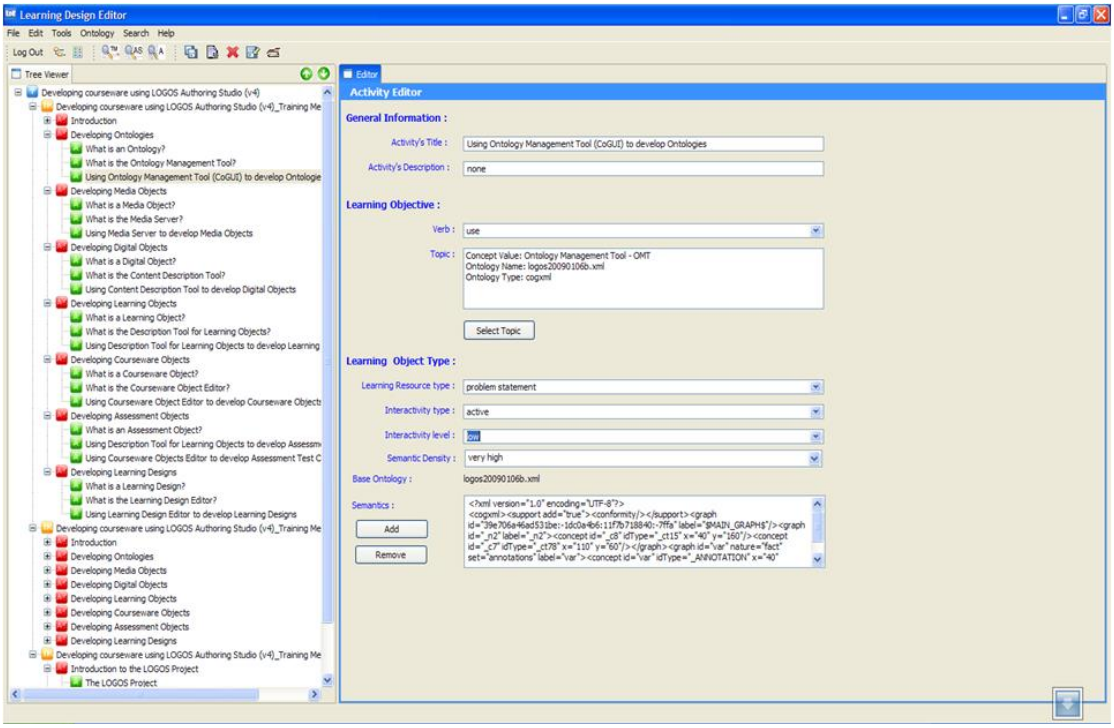

Figure 5.4 The Learning Designs Editor User Interface

5.2.4. Dynamic Courseware Creation Middleware

The personalization framework proposed in this thesis has been implemented in LOGOS to support pedagogically-sound personalized learning experiences on top of its repositories [Arapi, Moumoutzis, Mylonakis, Theodorakis, and Stylianakis, 2007; Arapi, Moumoutzis, Mylonakis, Stylianakis, Theodorakis, and Christodoulakis, 2008; 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 elements of the Learner Model presented in this thesis representing the cognitive 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.

The Dynamic Courseware Creation Middleware in LOGOS architecture implements the functionality of the Personalization Middleware presented in the proposed framework performing the dynamic creation of a personalized learning experiences 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.

The generated learning experience is transformed to a courseware object by the Transformation Component according to the METS-based approach of the framework presented in this thesis. 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 to use a SCORM compliant LMS. In this case the CO will be transformed to a SCORM package before delivering it to the LMS.

The transformation of the generated learning experience intermediate format to the METS-based representation of CO and futher to SCORM package has been described in Chapter 4. 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 Chapter 4. This software has been implemented in Java, using also other technologies for XML documents management as XQuery and XSLT.

5.2.5. Delivery components

Delivery components allow the delivery of learning experiences through different devices (e.g. PC, mobile and digital TV).

In Appendix 4 the integration of the personalization functionality in LOGOS Learning Management System is described in detail using use cases. Moreover, the descriptions of the web services related with the personalization functionality are also presented.

5.3. Natural Europe project

Natural Europe project aimed at taking advantage NHMs' content by making it available online and using it to create meaningful educational experiences within the museums themselves. Natural Europe aim was to offer to the museums the tools that will allow them to continuously manage and publish their digital collections online. The project exposed this cultural content from NHMs in Europe, to Europeana. This content is being used to develop educational pathways that visitors can use to navigate both physically and virtually through NHM exhibitions, connecting them with the school curriculum. The major objective of the project was to take advantage of this high quality content found in the NHMs and SCs for educational purposes. The purpose is through meaningful learning experiences to bring museum education closer to the schools. Teachers and museum educators can create their own educational activities connected to school curriculum including either physical or virtual museum visits. [Palavitsinis and Tsilibaris, 2011]

Methodology and solutions proposed in this thesis were applied and implemented in Natural Europe project to support the need of Natural History Museums to make available their cultural digital collections and support their gradual repurposing to develop pedagogy-driven learning experiences in the form of educational pathways based on educational templates encoding instructional strategies to support different learning scenarios [Mylonakis, Arapi, Moumoutzis, Christodoulakis, and Ampartzaki, 2013; Makris, Skevakis, Kalokyri, Arapi, Christodoulakis, Stoitsis, Manolis, and Leon Rojas, 2013; Makris, Skevakis, Kalokyri, Arapi, and Christodoulakis, 2013; Makris, Skevakis, Kalokyri, Arapi, and Christodoulakis, 2014].

The user roles/stakeholders involved are the following:

- **Curators**: The museums provide digital contents originating from various collections. The creation and administration of this content is handled museum-internally and in the authority of the respective collection curators. In this case the term curator includes any staff member responsible for authoring collection contents.

- **Educators**: The most important target user group for Natural Europe is educators. Educators both consume and provide learning contents through the educational services offered by the Natural Europe platform. At the beginning of the project the creation of educational content is done mainly by museum educators already familiar with the specific contents of their institution, but the services are also used by external educators, like kindergarten educators, school teachers, university educators, educators in life-long learning institutions etc.

- **Visitors**: The term visitor includes any private person using the Natural Europe services. A visitor may be an online visitor of a museum's web pages or a real-life visitor inside the museum. Learners who use the platform in the context of activities triggered by their educators are included as well as private persons, like parents preparing a family visit to the museum of just interested private persons. In case a distinction between parts of the visitor user group becomes necessary, it is being stated in the text.

5.3.1. Natural Europe architecture

Figure 5.5 presents the three main architectural parts of the Natural Europe (NE) architecture:

- The Natural Europe Cultural Infrastructure containing the tools for Cultural Heritage Objects (CHO) Publishing and Authoring, and the NE Cultural Federation and its interplay with external platforms (e.g. Europeana, ARIADNE).

- The Natural Europe Learning Infrastructure containing the tools for Pathway Authoring (including LOs) and Pathway Template Authoring, and the NE Learning Federation and its Interplay with external platforms (ARIADNE etc.)

- The end point interfaces (delivery components) containing: a) The Educational Pathway Navigation Interface, b) The Faceted Search interfaces and the corresponding Search Widgets for searching content from Europeana and the NE Cultural Federation, and c) the Interactive Installations.

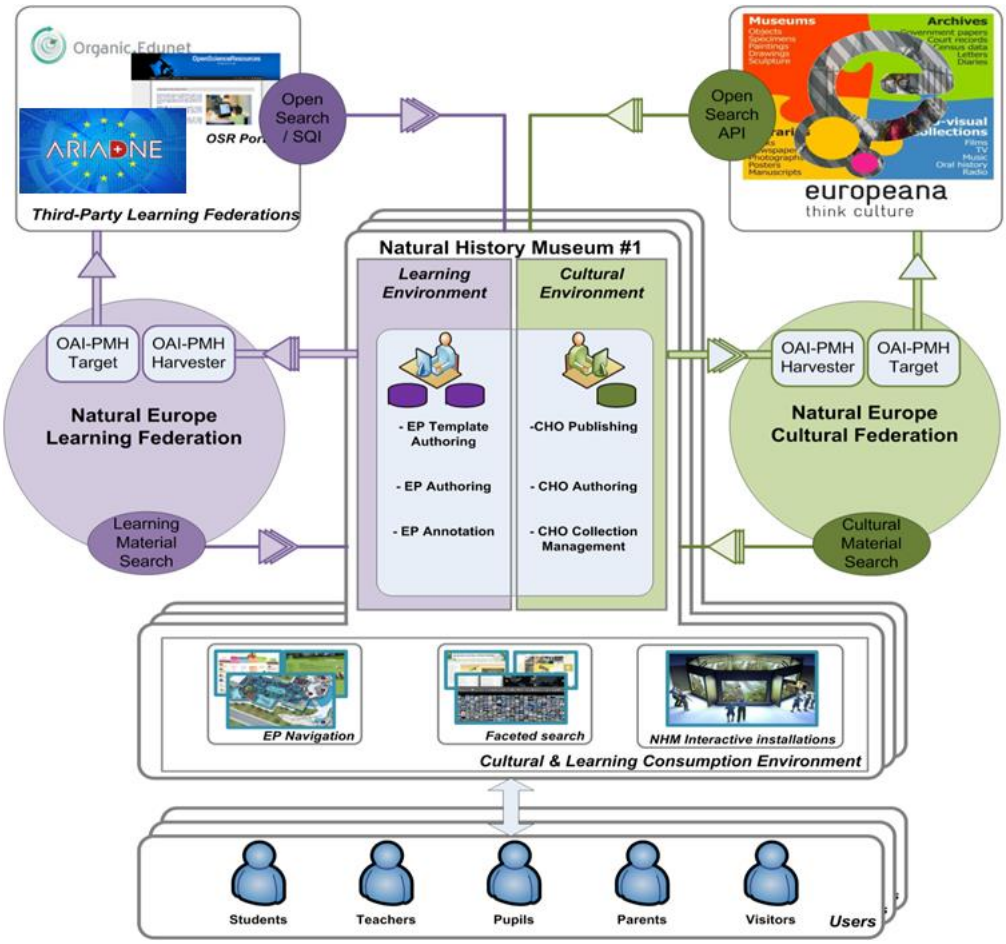

Figure 5.5 The Natural Europe Architecture

5.3.2. Natural Europe objects/repositories

Natural Europe follows a hierarchical approach in the categorization of the objects it manages, corresponding to the framework presented in this thesis:

Cultural Heritage Object (CHO): In Natural Europe, the term cultural heritage object represents any object originating from the natural history museums' collections. A CHO typically consists of a digital object and its descriptive metadata. The object itself may be born digital (for example a Microsoft Powerpoint presentation or an Adobe PDF document), or it maybe a digitized version of an analog object (like a photo of an exhibit or a scanned text page).

Learning Object (LO): Natural Europe defines LOs as digital objects, which are used in an educational context. These objects may be composed of several resources or they may be alone serving an educational objective.

Educational Pathway (EP): An educational pathway in Natural Europe is a complex activity mostly in an educational context. Such an activity is mostly composed of several

consecutive steps, representing either phases in a learning process that building up on each other, or representing an actual pathway through the museum, providing navigational assistance for thematically connected exhibits. Educational Pathways may use Learning Objects composed by Cultural Heritage Objects or other learning resources coming from external sources and federations such as Europeana and ARIADNE.

Educational Pathway Template (EPT): The educational pathways applied by educators in teaching scenarios in NE are mostly follow educational models for inquiry-based and informal learning activities. These educational models are represented in the Natural Europe system through educational pathway templates, providing a framework for the implementation of educational pathways that can be filled with the respective contents for various topics.

5.3.3. Natural Europe Authoring Tools

Natural Europe has developed tools for Digital Libraries that include mechanisms and methodologies for the semantic annotation of existing NHM content as well as its usage in multiple educational contexts.

The Natural Europe MultiMedia Authoring Tool (MMAT) [Makris, Skevakis, Kalokyri, Arapi, Christodoulakis, Stoitsis, Manolis, and Leon Rojas, 2013; Makris, Skevakis, Kalokyri, Arapi, and Christodoulakis, 2013; Makris, Skevakis, Kalokyri, Arapi, and Christodoulakis, 2014] is an online tool that allows curators to import, organize and describe their cultural digital collections. It helps them to annotate digital resources with metadata and properly classify them, creating Cultural Heritage Objects and facilitating their access and retrieval. The MMAT is adopts the latest version of the Natural Europe-CHO Application Profile based on ESE for the semantic description of CHOs.

The Natural Europe Educational Pathway Authoring & Annotation Tool (PAT) [Gkinis et al., 2012] is a multilingual web-based tool which allows teachers/educators to create EPs based on EP templates produced by learning experts. The produced learning objects and pathways are then rendered and made available for navigation in the Pathway Player. The PAT utilizes the CHO discovery service, which allows the retrieval of relevant content from the Natural Europe federated repositories. Alternatively, it may use the Europeana's Open Search API, to dynamically search and retrieve content from the Europeana.eu portal.

The Educational Pathway Template Authoring Tool, or Octopus [Mylonakis, Arapi, Moumoutzis, Christodoulakis, and Ampartzaki, 2013], is a web-based tool that refers to experts in educational design who will use it to develop templates to guide the development of educational pathways according to pedagogical models. The Educational Pathway Templates will be fed into the Educational Pathway repository, which is also accessed from the PAT in order to retrieve the Educational Pathway Templates. EPTAT

provides a user-friendly graphic environment that allows users to easily create, retrieve, update and delete Educational Pathway Templates and corresponding properties and metadata. The pathway templates that are developed with the tool are based on IMS LD Level A specification and can also be exported to SCORM packages. Finally, the tool provides the flexibility to use different LOM Application Profiles to describe the pathway templates and their integral parts opening the tool and the developed pathway templates to different audiences and stakeholders.

Two categories of templates have been designed in the context of Natural Europe: templates for Guided Pathways, which are based on inquiry-based, project-based, game-based learning approaches, and templates for Open Pathways, that are based on other educational approaches.

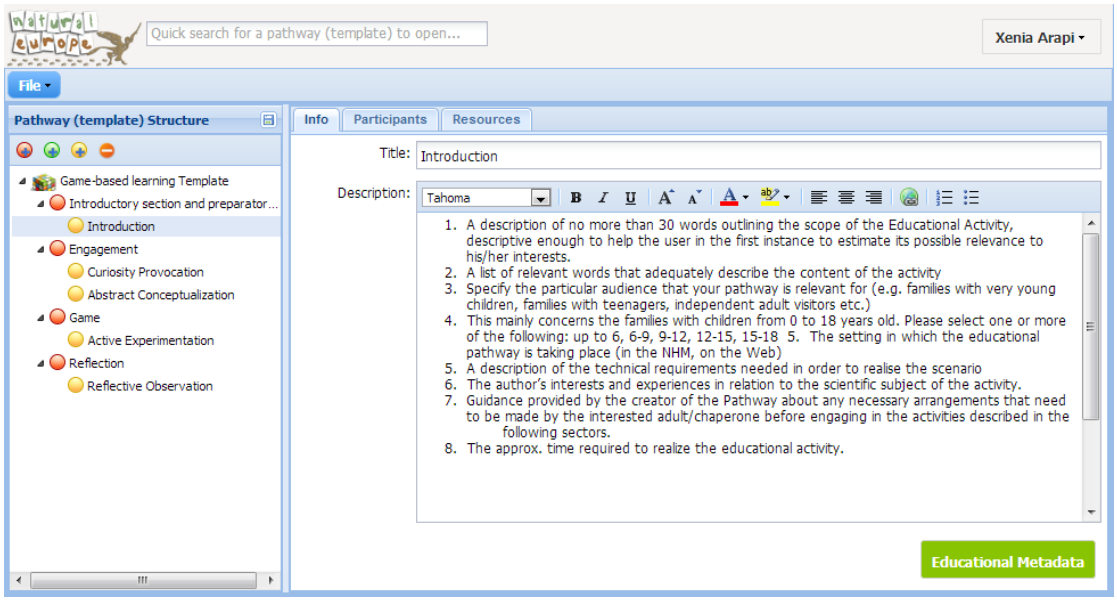

Figure 5.6 Developing an educational template for game-based learning in Educational Pathway Template Authoring Tool

5.3.4. Delivery components

The Cultural & Learning Consumption Environment provides interfaces for the web sites of the participating museums allowing them to interactively navigate through developed educational pathways and to perform faceted search in content of interest. The Faceted Search Web Interface developed in the form of content powered discovery microsites that were deployed by NHMs allowing searching (a) in one or more parts of their own collections, as well as (b) in relevant NHM content lying in Natural Europe repositories or in external sources. The Educational Pathways Web Interface allows the navigation through Educational Pathways. It actually serves as an Educational Pathway Player component (compatible to SCORM 2004) allowing museum site visitors to search/browse through the museum's pathways, preview their activities, and navigate through their online parts. Moreover, Interactive Installations set up in museums offer an

enhanced virtual navigation through the museum's collections supporting facetted browsing through the local collection of the museum as well as the contents of the federated repositories and Europeana. Also the navigation through educational pathways is supported.

5.4. Research project No. DN02/06/15.12.2016 funded by the Bulgarian Sciences Fund

Continuation of implementation and application of the PhD research is done as a series of papers published under the support of Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018) funded by the Bulgarian Sciences Fund and in specific in WP2: "Creating models and tools for improved use, research and delivery of digital cultural resources". The project conducts fundamental research in the areas of computer science, information and communication technology and partially in the humanities and social sciences with the goal of acquiring new knowledge on the fundamental causes of phenomena and observable facts in these areas without any direct commercial application or use.

5.5. Summary

In this chapter, the implementation of the framework and architecture proposed in this thesis in the context of LOGOS European project was presented, to support the need of accessing and repurposing existing multimedia contents residing in archives for the gradual development of pedagogy-driven personalized learning experiences in a static or dynamic way and their delivery through different channels. Moreover, this chapter presented the application and implementation of methodology and solutions proposed in this thesis in Natural Europe project to support the need of Natural History Museums to make available their cultural digital collections and support their gradual repurposing to Cultural Heritage Objects (CHOs), Learning Objects (LOs) and pedagogy-driven learning experiences in the form of Educational Pathways (EPs) based on Educational Templates encoding instructional strategies to support different learning scenarios. Natural Europe provided repositories and tools for supporting the development of the above types of objects, pathways and templates, their access from centralized points (federations) and further dissemination to Europeana and ARIADNE Learning Federations, as well as delivery components and interfaces for the web sites of the participating museums allowing them to interactively navigate through developed educational pathways and to perform faceted search in content of interest. Continuation of implementation and application of the PhD research is done as a series of papers published under the support of Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018) funded by the Bulgarian Sciences Fund.

Chapter 6. EXPERIMENTATION AND EVALUATION

6.1. Introduction

Different tools have been elaborated on the base of the proposed architecture. These tools were assessed and "verified" and validated on their usability. Experimentation and evaluation for repurposing and personalization in the proposed framework was conducted in the context of LOGOS project.

6.2. Experimental Setting

The validation of the LOGOS platform illustrated in detail in [Watterson, Pemberton, and Griffiths, 2009] combined "Formative and Summative evaluation". "Formative evaluation" is an evaluation of an unfinished user interface (e.g. via heuristic evaluation, cognitive walkthroughs), 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.

In the Summative evaluation phase, feedbacks of real end-users of the LOGOS system have been collected and analyzed [Corep, Eden, and UniBrighton, 2009]: authors and learners of ubiquitous learning materials. The reflections of the two target groups provided feedback on usability and personalization efficiency of the LOGOS system.

The feedbacks have been created after:

- Authors used the LOGOS Authoring Studio and playout systems following a selected set of authoring scenario.
- Learners took part of a ubiquitous learning experience, which is created based on a selected learning scenario.

The reflections of the two target groups provided 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.

To test the complete LOGOS framework and functionality, courseware was created in the domain of Bulgarian Iconography [Paneva-Marinova, Pavlova-Draganova, Draganov, and Pavlov, 2009]. Media Objects, Digital Objects, Learning Objects and Courseware Objects were developed and two learning designs to support "General to Specific" and "Example-oriented" learning styles and test the personalization functionality.

6.2.1. Authors

Within the LOGOS framework, it was decided to use for the Authors end-user evaluation the IsoMetric Questionnaire. The IsoMetrics Questionnaire comprises 75 items operationalizing 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, and 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.

6.2.2. Learners

During end-user experiments, feedback was collected from learners who used the LOGOS system via the specifically created coursewares by the LOGOS Authoring Studio. 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 the 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. 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).

6.3.1. 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 6.1).

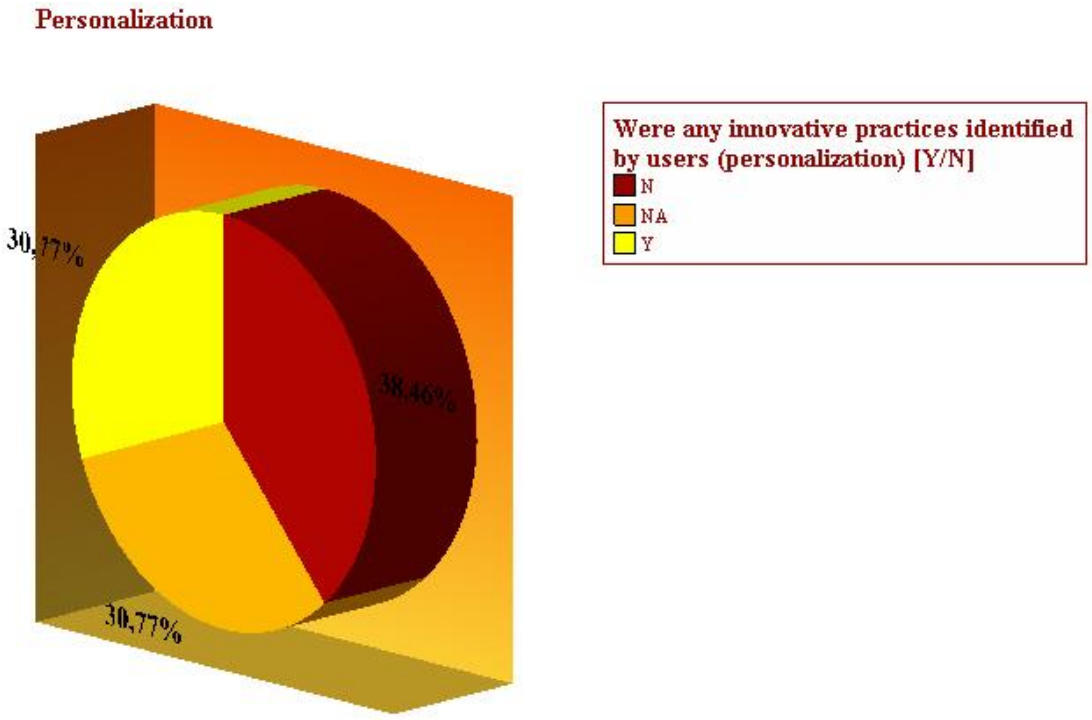

Figure 6.1 Authors' answers to the question "Were any innovative practices identified by users (personalization) [Y/N]"

Table 6.1 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 6.1 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	0.0% (0)	2.3% (1)	11.6% (5)	30.2% (13)	23.3% (10)	32.6% (14)	43

materials would shorten their learning time							
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

6.3.2. Learners

54.5% of the Learners experienced personalization, while 45.5% of them selected a static course (Figure 6.2).

18. I selected the personalized courses offered by Logos

	Response Percent	Response Count
Yes	54.5%	42
No	45.5%	35
answered question		77
skipped question		13

Figure 6.2 Learners that selected personalized courses vs. them that did not

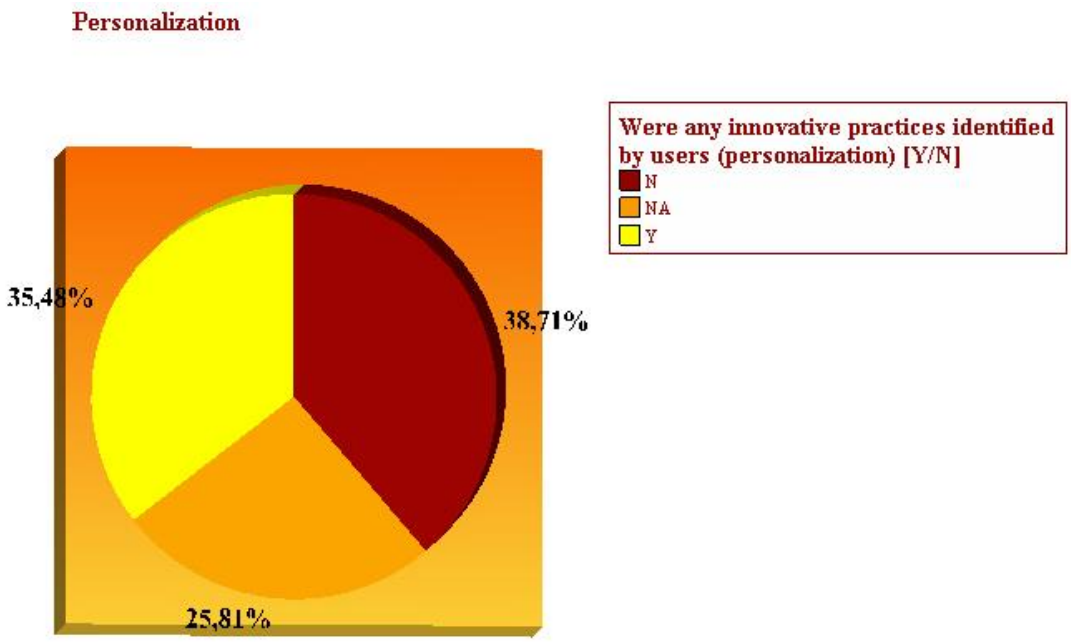

Figure 6.3 Learners' answers to the question "Were any innovative practices identified by users (personalization) [Y/N]"

35.48% of the Learners identified personalization as an innovative practice, as illustrated in Figure 6.3.

The personalization exercise was met with enthusiasm. Unfortunately, the tested scenario ("Bulgarian Iconography") did not offer personalized courses that matched the learning style of the testers, thus its efficiency/acceptance 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 6.2 gathers the Learners' assessment results to the questions related with personalization.

Table 6.2 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. The development of "Learning LOGOS through LOGOS" course

Due to the lack of different types of content and learning material to support different learning styles, the full potential of the proposed personalization framework could not be tested in the domain of Bulgarian Iconography. The author of this thesis had the idea to

use the LOGOS domain and the material created in the duration of this project to apply the proposed framework by developing digital objects, learning objects and learning designs to support personalized learning experiences for the training on LOGOS concepts and use of the developed authoring tools. During the project 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 expecially those that are intended for LOGOS Authors, i.e. the creators of learning content. This content after appropriate adaptation could be used for the development of learning objects to support different learning styles (i.e. Honey and Mumford's learning styles). E.g. it could support 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 Theorists along with manuals, tutorials and walkthroughs etc. Note also that the tools of the Authoring Studio themselves can be considered, in this approach, as an important element of the learning process supporting active learning.

Consequently, LOGOS domain provided a lot of material and tools that could be used to support all possible learning styles, either passive or active. Moreover, the author of this thesis, having the domain knowledge as a researcher in LOGOS project and adequate knowledge to develop instructional strategies and apply the framework to support different learning needs (such as learning styles), could undertake all user roles needed for the creation and re-purposing of the available resources and their exploitation in providing personalized learning experiences.

All the above, made the LOGOS domain ideal for testing the proposed personalization framework, but this idea came at the right time to serve in parallel another important need. Most of the knowledge acquired in LOGOS 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 and apply the proposed framework 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 would help 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.

The author of this thesis undertook the whole implementation of this idea: She developed a domain ontology representing the LOGOS domain, created content assets from available resources and digital objects semantically annotated with this ontology, developed learning objects exploiting those digital objects to support different learning styles and abstract training scenarios in the form of Learning Designs to support the development of pedagogy-driven personalized learning experiences based on these learning styles.

A number of media (raw content) was 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.

In the next sections the development phases of the LOGOS domain course are described organized as follows:

1) Development of a domain ontology describing the LOGOS Project domain

2) Development of the learning resources including:

    - 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 all Honey & Mumford's learning styles (Activists, Reflectors, Theorists, Pragmatists)

6.4.1. 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 6.4 and Figure 6.5). The ontology describing the LOGOS 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 Learning Designs.

The full domain ontology in the form of Conceptual Graphs XML (COGXML) can be downloaded from http://www.softnet.tuc.gr/~xenia/logos_ontology_final.cogxml

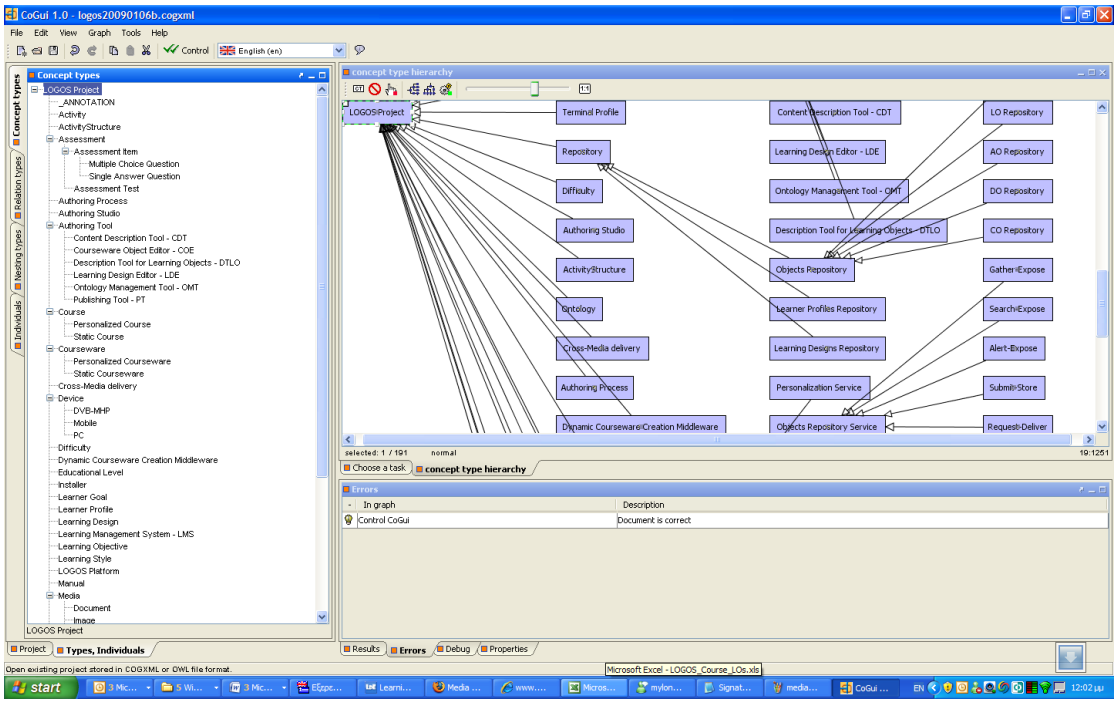

Figure 6.4 LOGOS Ontology Concepts (created with LOGOS Ontology Management Tool – CoGUI)

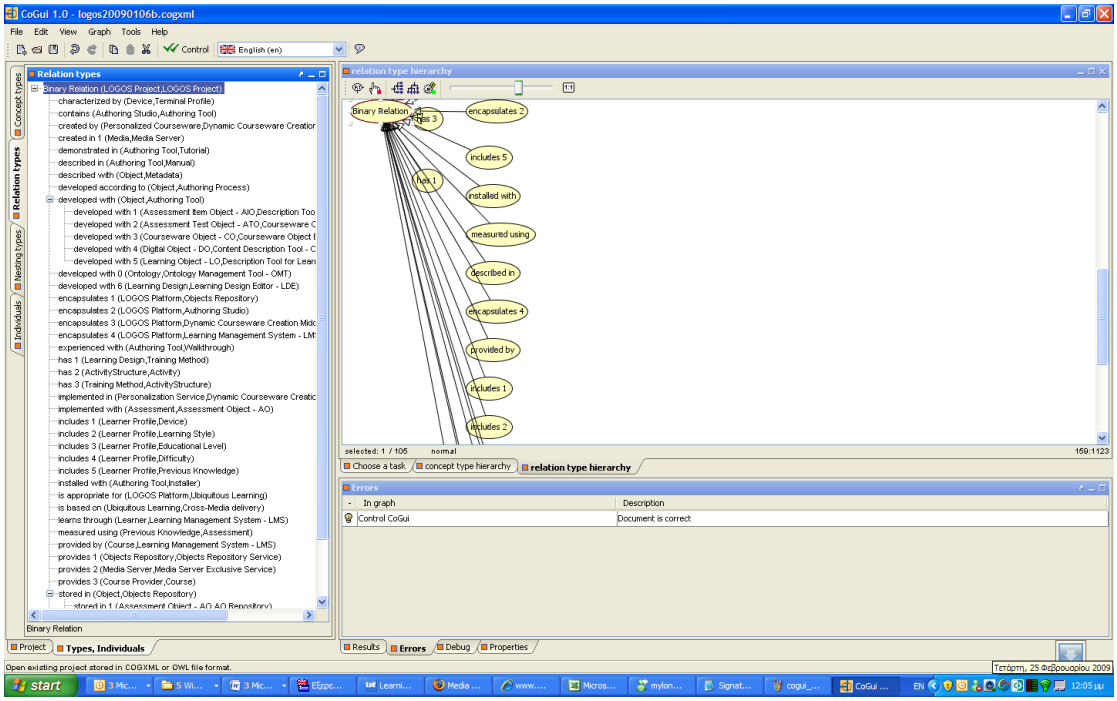

Figure 6.5 LOGOS Ontology Relations (created with LOGOS Ontology Management Tool – CoGUI)

Figure 6.6 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

6.4.2. Development of Media Objects

Media Objects (MOs) have been created corresponding 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.) has been selected and extracted from

available training materials regarding LOGOS domain and has been uploaded and registered to the Media Server, forming the so called Media Objects (Figure 6.6).

6.4.3. Development of Digital Objects

A big number of Digital Objects (DOs) has been created on top of Media Objects correspond to Media Objects or parts of them annotated and indexed with administrative and semantic metadata has been created on top of Media Objects using the Content Description Tool (CDT), as illustrated in Figure 6.7 and Figure 6.8 and which could be accessed and browsed through the same tool.

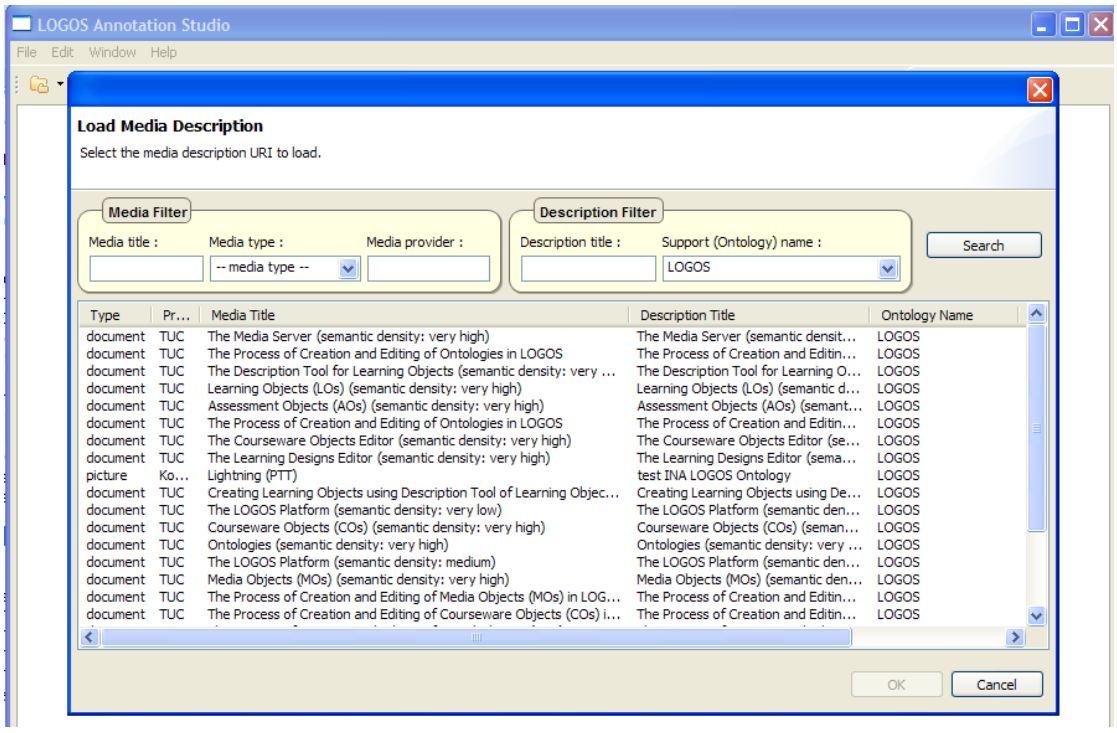

Figure 6.7 A number of annotated Media Objects (Digital Objects) that have been created for the LOGOS domain using Content Description Tool (CDT)

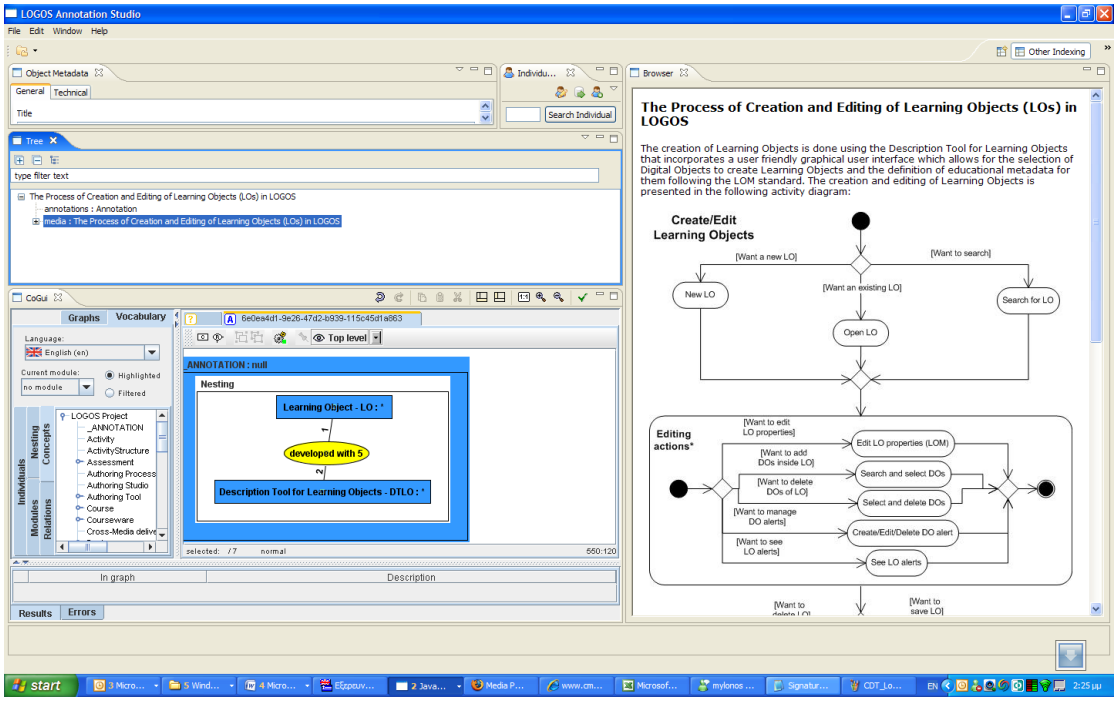

Figure 6.8 Annotation of a Media Object for the LOGOS domain through Content Description Tool (CDT)

6.4.4. 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 Chapter 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). A big number of LOs with different characteristics encoded in LOM metadata (learning resource type, interactivity type, interactivity level, semantic density and learning objectives) has 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 6.9 and Figure 6.10).

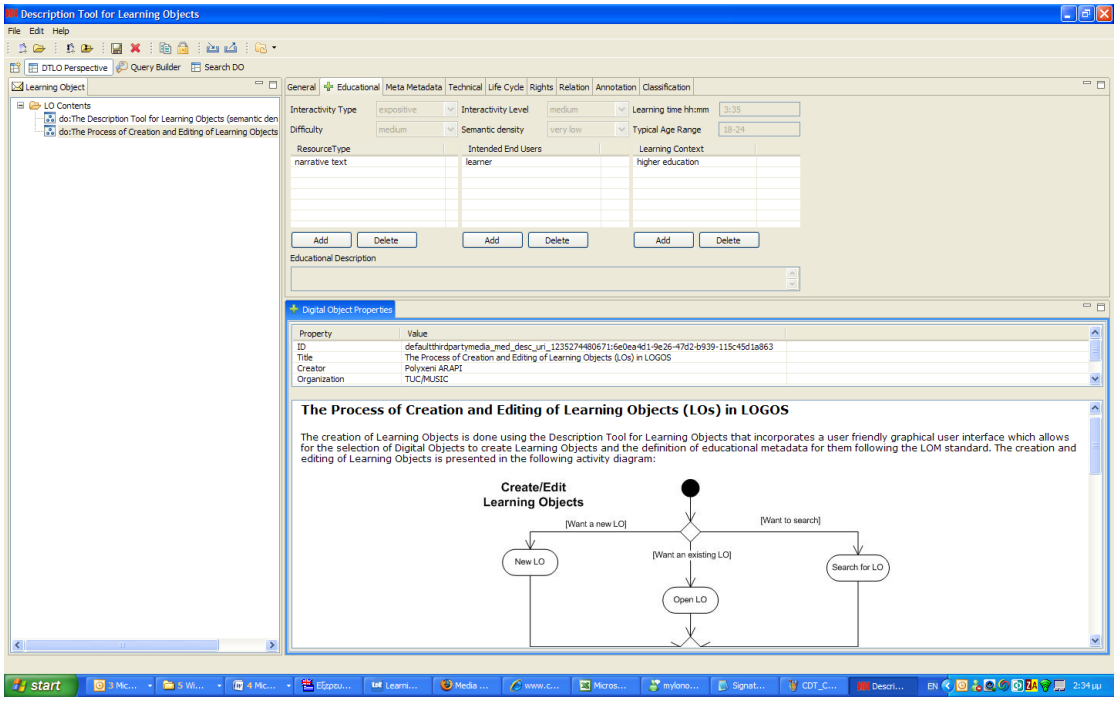

Figure 6.9 Creation of a Learning Object regarding LOGOS domain using the Description Tool for Learning Objects (DTLO)

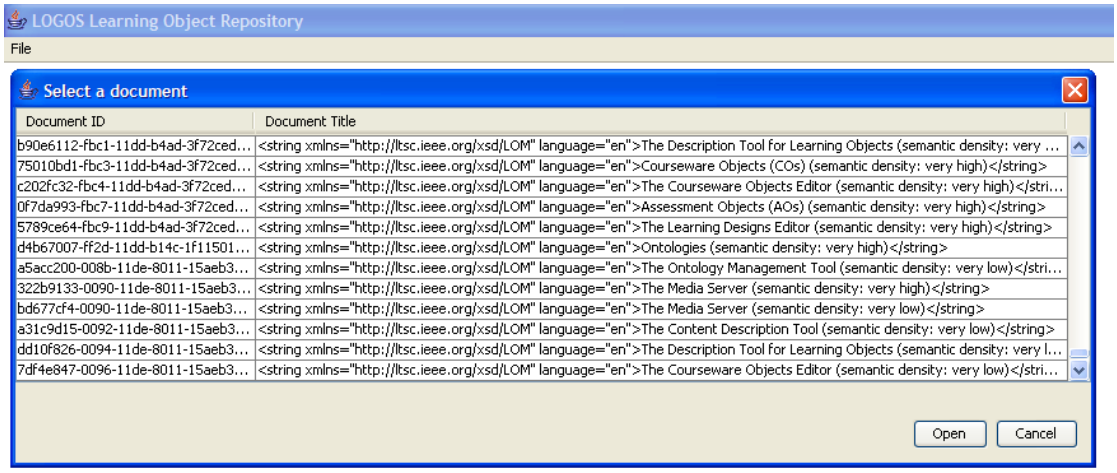

Figure 6.10 A number of LOs that have been developed for the LOGOS domain and retrieved from the Learning Objects Repository

In Appendix 6 the Learning Objects developed for the LOGOS course and their properties defined in the corresponding LOM metadata are presented.

6.4.5. Development of Learning Designs to support Honey & Mumford's learning styles

Appropriate Learning Designs including training methods to teach the LOGOS domain to Learners with different learning styles according to Honey and Mumford have been developed with the Learning Designs Editor (LDE) (Figure 6.11). In Appendix 6, these methods are presented along with the best fit Learning Objects that will be selected from

the LOGOS personalization process and bound on the training methods activities at run-time for each learning style.

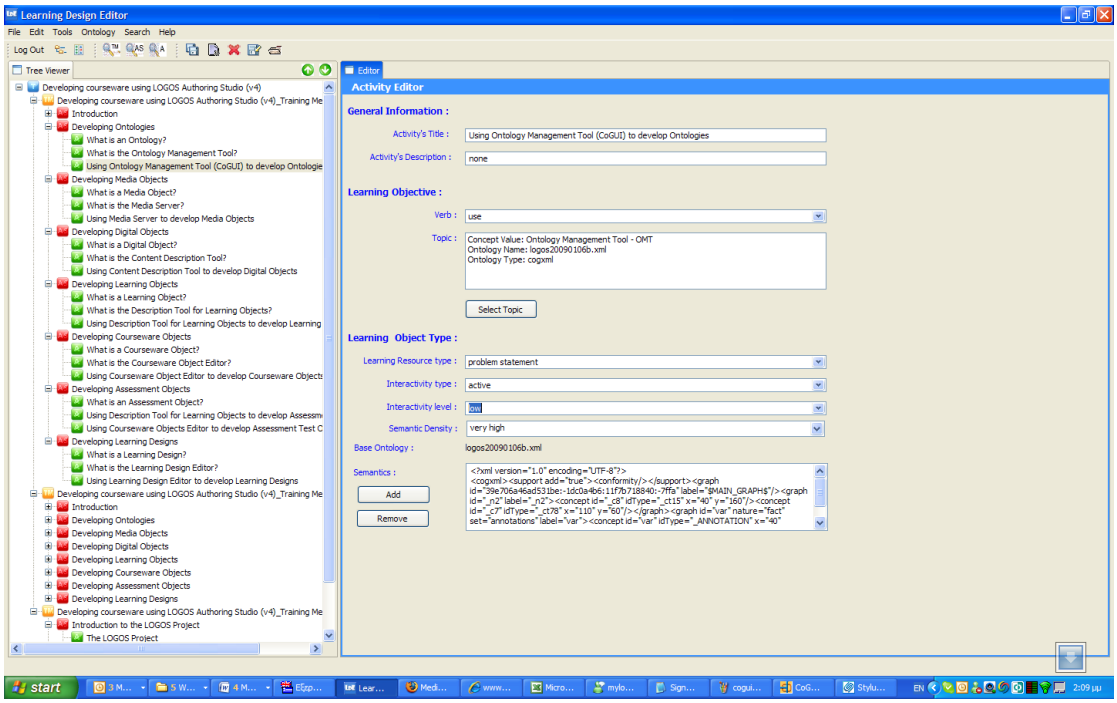

Figure 6.11 Development of Learning Designs with different training methods for teaching the LOGOS domain in order to support Honey and Mumford learning styles implemented using the Learning Designs Editor (LDE)

6.5. Summary

This chapter presented how the experimentation and evaluation of the proposed framework, was performed in the context of LOGOS project. The experiments have shown a positive acceptance from the end users (Authors and Learners). Personalization advantages have been supported both by Authors and Learners groups of experiment participants.

LOGOS domain performed ideal for testing the proposed personalization framework. Supported activities allowed 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 Theorists along with manuals, tutorials and walkthroughs etc. During the tests authors were able also to play the user roles of LOGOS back-end: Knowledge Managers, Media Integrators, Annotators/Indexers, Educationalists, Courseware Developers, and Learning Designers. A number of media (raw content) was 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.

As a conclusion, in order for the framework presented in this thesis to work well and efficiently towards the provision of personalized learning experiences fitting the needs of

different learners and maximizing the learning outcome, a change in the philosophy of courseware authors and learning designers and a little more effort by them is needed in order to develop learning content beyond the "one size fits all" approach. Towards this end they need to develop different versions of learning objects and courseware to fit different learning styles and needs according to instructional strategies. However, one one hand the fact that this requires more effort by them and on the other hand the fact that they usually lack the pedagogical knowledge to support this process, prevents or discourages them to follow such an approach or create quality learning objects. Here, learning designs as abstract training scenarios in this framework, encoding training methods based on instructional strategies, developed by instructional design experts and pedagogists through the provided tools are very useful to fill the pedagogical knowledge gap. Moreover, the reusability of learning objects and the dynamic creation of personalized courseware supported by this framework, which can be also exploited by courseware authors, can reduce their effort in the development of courseware.

CONCLUSION

The goal of this thesis was to provide a comprehensive approach for taking advantage of existing cultural digital materials residing in cultural heritage institutions to support the creation and provision of effective pedagogy-driven learning experiences not only in the context of cultural heritage preserved in these institutions, but also to serve other learning contexts and scenarios, providing solutions from user's point which support the needs of institutions preserving cultural heritage through opening their cultural collections to the learning community and their visitors and supporting effectively formal and informal learning applications on top of them, support the educators and teachers accessing cultural digital content residing in those institutions collections and developing learning experiences to effectively support the needs of different learners in a pedagogically-sound way maximizing the learning outcome and which support Learners with different needs and preferences accessing cultural material in an effective pedagogy-driven personalized way.

In solving the main problems leading to the achievement of the goal and the objectives of this thesis (see Chapter 1, Section 1.2. "Goal, objectives and tasks of the thesis"), made scientific and applied research and concrete results as follows:

- Developed a framework and models for supporting effective personalized learning services on top of multimedia digital libraries, by a) supporting re-purposing of multimedia digital content/archives to cultural digital objects, learning objects and higher learning units, b) supporting the construction of pedagogy-driven personalized learning experiences on top of multimedia digital archives statically or dynamically. Towards this end defined 4 models: domain model, learner model, instructional model and adaptation model.

- Developed an integrated service-oriented architecture and functional components (including repositories, tools, delivery components, applications and services) based on interoperability-standards to support repurposing of existing multimedia digital content to cultural digital objects, learning objects and higher learning units for the construction of pedagogy-driven personalized learning experiences statically or dynamically. The architecture supports interoperability and sharing of cultural digital objects, learning objects and learning experiences with existing eLearning systems and large repositories/aggregators.

- Implementation of the proposed framework and architecture in LOGOS project and application of the proposed methodology and solutions in the implementation of Natural Europe project to support the need of Natural History Museums to make available their cultural digital collections and support

their gradual repurposing to develop pedagogy-driven learning experiences with the use of educational pathways based on educational templates.

In the implementation of Task 1 (Study of the problem) has achieved the following results:

- Studied the concepts and components of digital libraries and digital objects, as well as eLearning systems and learning objects and content models (see Chapter 2, Section 2.2 "Digital Libraries", Section 2.3 "eLearning systems").

- Studied main interoperability standards, specifications and approaches for the description, packaging and access of (cultural) digital objects and learning objects, and for repositories interoperability (see Chapter 2, Sections 2.4, 2.5 and 2.6 respectively).

- Studied personalization in Digital Libraries and learning: approaches for personalization in DL, user modeling and profiling; the characteristics of the Learner user and how they (should) affect personalization processes; the role of pedagogy and instructional design/strategies in personalization, pedagogical patterns, and IMS LD specification for instructional design; approaches for adaptive personalization in eLearning (see Chapter 2, Sections 2.7.1, 2.7.2, 2.7.3 and 2.7.4 respectively).

- Analyzed in detail the complex problem of interoperablity this thesis tries to address from an objects, infrastructures and personalization point of view (see Chapter 2, Section 2.8).

- Presented the envisioned scenario of this thesis; Investigated approaches and solutions related with re-purposing of multimedia objects to learning objects and adaptive pedagogy-driven personalization and compared them with the proposed solution (see Chapter 2, Section 2.9).

In the implementation of Task 2 (Modeling the environment to support pedagogy-driven personalization) has achieved the following results:

- Defined the domain model: Following the Learnativity Model defined how learning experiences can be gradually developed from digital content assets coming from GLAM archives. Such a categorization is important to define the granularity of these objects and their characteristics to support personalization. The detailed representation of these objects and their relations was developed using the METS digital library standard as the basis for combining various schemata necessary to describe Digital Objects, reusable Learning Objects, Assessment Objects and Learning Components. LOM was selected for the

representation of educational metadata for both Learning Objects and Learning Components. Semantic metadata can be represented using several metadata schemes, domain ontologies, taxonomies or vocabularies. The authoring/repurposing process and pedagogical aspects and requirements for the proper description and structuring of the object layers to support pedagogy-driven personalization were also described. (see Chapter 3, Section 3.2)

- Defined the learner model: The learner characteristics identified in Chapter 2 as important parameters to support personalization were modeled. These are exploited during the dynamic creation of personalized learning experiences in order to select appropriate training scenarios to guide the learning experiences creation process and furthermore to select appropriate reusable Learning Objects to be linked with learning activities in order to create personalized learning experiences. (see Chapter 3, Section 3.3)

- Defined the instructional model: The pedagogy-driven personalization is based on abstract training scenarios that capture the pedagogical approached to teach a subject taking into account the individual learning styles, educational level, preferred difficulty and other preferences of the learners. The definition and representation of these abstract training scenarios was based on a specific instructional ontology that takes into account related standards and overcomes their shortcomings. (see Chapter 3, Section 3.4)

- Defined the adaptation model: The adaptation process is encapsulated in an appropriate personalization algorithm that exploits information from the Learner model to firstly select appropriate abstract training scenarios matching Learner's needs and preferences and proceeds with the binding of appropriate reusable Learning Objects to the learning activities of the selected scenario. The same mechanism can be used to construct assessment tests from assessment objects that can be used for the identification of the previous knowledge of the Learner. (see Chapter 3, Section 3.5)

In the implementation of Task 3 (Architecture) has achieved the following results:

- Developed an integrated service-oriented architecture based on interoperability-standards to support repurposing of multimedia digital content to cultural digital objects, learning objects and higher learning units for the construction of pedagogy-driven personalized learning experiences on top of existing cultural digital collections statically or dynamically (see Chapter 4, Section 4.2).

- Described the functionality of its components including repositories, authoring/repurposing tools, personalization component and transformation component (see Chapter 4, Sections 4.2.1, 4.2.2, 4.2.3 and 4.2.4 respectively).

In the implementation of Task 4 (Implementation and application of the proposed framework and architecture) has achieved the following results:

- Implementation of the proposed framework and architecture in LOGOS project (see Chapter 5, Section 5.2).

- Application of the proposed framework in the implementation of Natural Europe project (see Chapter 5, Section 5.3).

- Continuation of implementation and application of the PhD research as a series of papers published under the support of Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018) funded by the Bulgarian Sciences Fund (see Chapter 5, Section 5.4).

In the implementation of Task 6 (Experimentation and evaluation) performed experimentation and evaluation of the proposed framework in the context of LOGOS project (see Chapter 6).

CONTRIBUTIONS OF THE THESIS

Major scientific and applied contributions of the thesis are:

- Developed a framework and models for supporting effective personalized learning services on top of multimedia digital libraries, by a) supporting re-purposing of multimedia digital content/archives to cultural digital objects, learning objects and higher learning units, b) supporting the construction of pedagogy-driven personalized learning experiences on top of multimedia digital archives statically or dynamically. The following models have been defined:

    - Domain model: a) Defined the object layers from content assets, to cultural digital objects, to learning/assessment objects and learning components, and their description, structuring and relation exploiting METS, LOM and other standards to support pedagogy-driven personalization; b) Specified the authoring/repurposing process and pedagogical aspects and requirements for the proper description of learning objects to support pedagogy-driven personalization (e.g. different learning styles) without being tied to a specific learning style taxonomy.

    - Learner model: Identified important learner characteristics and preferences that should be taken into account in personalization process and encoded them in an ontology.

    - Instructional model for the encoding of instructional strategies as abstract training scenarios (educational templates) taking into account related standards as IMD LD. These templates are reusable and separated from content, allowing appropriate learning resources according to the Learner profile and current context to be bound to the training scenario at run-time.

    - Adaptation model: The adaptation process is encapsulated in an appropriate personalization algorithm that exploits information from the Learner model to firstly select appropriate abstract training scenarios matching Learner's needs and preferences and proceeds with the binding of appropriate reusable Learning Objects to the learning activities of the selected scenario. The same mechanism can be used to construct assessment tests from assessment objects that can be used for the identification of the previous knowledge of the Learner.

- Developed an integrated service-oriented architecture and functional components (including repositories, tools, delivery components, applications and services) based on interoperability-standards to support repurposing of existing

multimedia digital content to cultural digital objects, learning objects and higher learning units and construction of pedagogy-driven personalized learning experiences statically or dynamically. The architecture supports interoperability and sharing of cultural digital objects, learning objects and learning experiences with existing eLearning systems and large repositories/aggregators.

- Implementation of the proposed framework and architecture in LOGOS project and application of the proposed methodology and solutions in the implementation of Natural Europe project to support the need of Natural History Museums to make available their cultural digital collections and support their gradual repurposing to develop (statically) pedagogy-driven learning experiences with the use of educational pathways based on educational templates.

Results from the research done in a number of **European Research & Development projects** (listed below) were combined, enriched, specialized and applied in the PhD thesis for the domain of cultural digital libraries:

- The framework presented in this thesis has been exploited in Research project No. DN02/06/15.12.2016 "Concepts and Models for Innovation Ecosystems of Digital Cultural Assets" (2016 - 2018), funded by the Bulgarian Sciences Fund, and in specific in WP2: "Creating models and tools for improved use, research and delivery of digital cultural resources". The project will conduct fundamental research in the areas of computer science, information and communication technology and partially in the humanities and social sciences with the goal of acquiring new knowledge on the fundamental causes of phenomena and observable facts in these areas without any direct commercial application or use.

- The work presented in this thesis was implemented in IST/STREP **LOGOS project** "Knowledge-on-Demand for Ubiquitous Learning" (IST-4-027451) (**common project of TUC/MUSIC with IMI-BAS**), where a Knowledge-on-Demand ubiquitous learning platform was developed, 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 framework and architecture proposed were applied and implemented to support the needs of repurposing of existing multimedia material and the gradual development of pedagogy-driven personalized learning experiences in a static or dynamic way. Publications in the context of LOGOS project: [Arapi, Moumoutzis, Mylonakis, Theodorakis, and Stylianakis, 2007; Arapi, Moumoutzis, Mylonakis, Stylianakis, Theodorakis, and Christodoulakis, 2008]

- Methodology and solutions proposed in this thesis were applied in the implemention of the ICT/PSP **Natural Europe project** "Natural History & Environmental Cultural Heritage in European Digital Libraries for Education" (FP7-ICT-PSP: 250579) to support the need of Natural History Museums to make available their cultural digital collections and support their gradual repurposing to develop pedagogy-driven learning experiences with the use of educational pathways based on educational templates. The author of this thesis was not only a senior researcher in the realization of the project, but also one of the main authors of Natural Europe proposal where she proposed to apply this framework methodology and solutions successfully implemented in LOGOS to support these objectives. Publications in the context of Natural Europe project: [Mylonakis, Arapi, Moumoutzis, Christodoulakis, and Ampartzaki, 2013; Makris, Skevakis, Kalokyri, Arapi, Christodoulakis, Stoitsis, Manolis, and Leon Rojas, 2013; Makris, Skevakis, Kalokyri, Arapi, and Christodoulakis, 2013]

- Parts of the methodology and tools presented in this thesis were applied to LdV/ToI **QONIAon project** "VET Qualification Practice for e-Inclusion" (2013-1-TRI-LEO05-47585) (**common project of TUC/MUSIC with IMI-BAS**) promoting the idea for e-facilitator as instrument for e-Inclusion with it's curriculum, methodology, technology, experience, appropriate LMS, content and use case scenarios. The proposed solutions were applied to support the development of its curriculum, its description, provision and further dissemination. Publications in the context of QONIAon project: [Mylonakis, Arapi, Moumoutzis, Christodoulakis, and Ampartzaki, 2013; Mylonakis, Arapi, Pappas, Moumoutzis, and Christodoulakis, 2011]

- Finally, results of this thesis related with instructional design have been applied in ICT/PSP **Open Discovery Space project** "A socially-powered and multilingual open learning infrastructure to boost the adoption of eLearning resources" (FP7-ICT-PSP: 297229). Publications in the context of ODS project: [Stylianakis, Moumoutzis, Arapi, and Christodoulakis, 2013; Stylianakis, Moumoutzis, Arapi, Mylonakis, and Christodoulakis, 2014].

Furthermore, parts of the work done in the scope of this thesis have been published in a number of **peer reviewed journals and conference proceedings** (see "LIST OF THE AUTHOR'S PUBLICATIONS RELATED WITH PHD THESIS"): International Journal on Digital Libraries - IJDL (Springer, 2014) and International Journal of Education and Information Technologies (NAUN, 2016), 6th International Conference on Web-based Learning - ICWL 2007 (Edinburgh, UK, 2007), IEEE International Conference on Advanced Learning Technologies - ICALT 2007 (Niigata, Japan, 2007), Workshop on Cross-Media and Personalized Learning Applications on top of Digital

Libraries (LADL2007) in conj. with ECDL2007 Conference (Budapest, Hungary, 2007), 2nd LOGOS Open Workshop on "Cross-Media and Personalized Learning Applications with Intelligent Content" (LAIC 2008) in conj. with AIMSA2008 Conference (Varna, Bulgaria, 2008), Metadata Semantics and Research Conference - MTSR2011 (Izmir, Turkey, 2011) and MTSR2013 (Thessaloniki, Greece, 2013), 2nd International Conference on E-Learning, and E-Technologies in Education - ICEEE 2013 (Lodz, Poland, 2013), 17th International Conference on Theory and Practice of Digital Libraries - TPDL2013 (Valetta, Malta, 2013), IEEE Interactive Mobile Communication Technologies and Learning - IMCL2014 (Thessaloniki, Greece, 2014), and International Conference on e-Learning - eLearning'16 (Bratislava, Slovakia, 2016). About 40 citations have been detected.

The work presented in this thesis can be extended or further developed in the following directions:

- Theoretical direction: 1) Extension/adaptation of the developed models towards supporting re-purposing and transformation of a digital library content and provision of personalized experiences in other domains and applications (at the same time), such as eScience, eResearch etc. This extension is possible since the proposed framework is generic enough to support multiple-context views of the content of a digital library and its transformation targeting at different applications. 2) Extension and exploitation of the framework to support the construction of Personal Learning Environments (PLEs), combining tools, services and resources, which learners use to direct their own learning and pursue educational goals.

- Applied/practical direction: Implementation and experimentation with other applications (eScience, eResearch etc.) on top of digital libraries, i.e. to offer services and tools supporting re-purposing of the underlying content, and provision of effective personalized experiences by real-time integration of content, tools and services to fit the needs of different target groups.

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APPENDIX 1: Objects XML representation

A. Digital objects (technical metadata)

Two simple examples of an image and a video segment focusing on their technical 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 0.1 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 0.2 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>
             <MediaDuration>PT00H00M03S26116N30000F</MediaDuration>
            </MediaTime>
          </VideoSegment>
        </TemporalDecomposition>
      </Video>
    </MultimediaContent>
   </Description>
</Mpeg7>
```

B. Learning objects

In Table 0.3 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 0.3 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>
                        <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>LOR</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>
</mets>
```

C. Assessment objects

An example of an Assessment Item is given in Table 0.4.

Table 0.4 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 example of an Assessment Test is given in Table 0.5.

Table 0.5 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>
```

An example of an Assessment Item Object is given in Table 0.6.

Table 0.6 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">
            <fptr FILEID="MH_FILE_1"/>
        </div>
    </structMap>
</mets>
```

Similarly, the METS representation of an Assessment Test Object is presented on Table 0.7 including the reference to the corresponding Assessment Test QTI description and its educational and administrative metadata.

Table 0.7 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.imsglobal.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.imsglobal.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>
```

D. Learning Components

An example of a Learning Component represented with METS according to the framework presented in this dissertation is given in Table 0.8.

Table 0.8 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.imsglobal.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.imsglobal.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/htm</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="CO147068763064020" 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 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>
```

APPENDIX 2: Boolean and Fuzzy LOM filters

A. Boolean LOM filters

Boolean LOM filters are used in order to make searches in the Learning Objects Repository as well as in the Assessment Object Repository and the Courseware Objects Repository exploiting the learning metadata that the corresponding objects contained expressed in LOM. Boolean LOM are structured as Boolean syntax trees. Lower level nodes are atomic conditions (atoms) defined over the set of elements specified by LOM. Conjunctive or disjunctive terms are defined on top of atoms using the Boolean operators AND, OR respectively. These are called lower level terms (LTerms). Higher level terms are defined on top of LTerms using again the boolean operators AND, OR. These are called upper level terms (UTerms). A filter (query) is defined as a conjunctive or disjunctive expression of the UTerms. The following figure depicts this hierarchical structure of Boolean LOM filters.

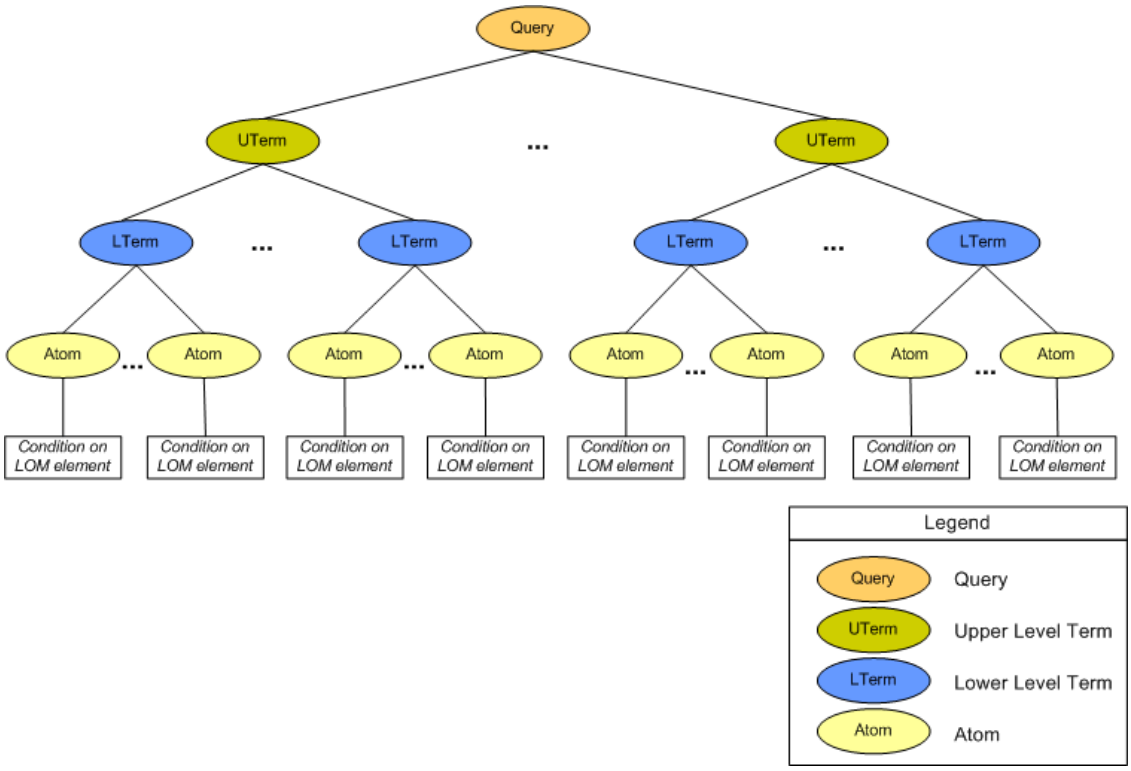


Figure 0.1 General structure of a Boolean LOM filter

The root node of a filter as well as the UTerm, LTerm and Atom nodes, apart from the Boolean operator (AND, OR) that corresponds to them, also contain a flag signifying if the corresponding Boolean expression should be negated or not. I.e. this flag signifies the presence of the Boolean NOT unary operator. Incorporating this flag, Atom nodes can express positive or negative conditions on LOM elements while LTerm, UTerm and Query nodes can specify positive and negated conjunctions and disjunctions (AND, OR, NOT AND, NOT OR boolean expressions).

Below each Atom node, as already stated, there is a condition on a certain LOM element. There are two basic types of such conditions:

- Conditions that refer to simple LOM elements: In this case the condition is expressed as a triple of the form <attr,op,value> where 'attr' is the corresponding LOM element, 'op' is a relational operator and 'value' is the specific value that is tested using the relational operator. For example such triples could be:

    - <educational_interactivityLevel,=,high>

      This condition signifies a search for objects that have, in their LOM metadata, the interactivityLeval element under the educational element, and its value is 'high'. For simplicity we may express this condition as educational_interactivityLevel=high.

    - <technical_format,=,MHP>

      This condition signifies a search for objects that have, in their LOM metadata, the format element under the technical element, and its value is 'MHP'. For simplicity we may express it as technical_format=MHP.

  Each simple LOM element can be of four types: String (containing also a language attribute specifying the language of the string text), String with no language attribute, Number and Vocabulary (it is an enumeration of values). Note that for each type, appropriate relational operators are defined: For Strings the operators supported are lexicographic ordering operators (<. >, =, !=, >=, <=) as well as the operator 'contains' to test for string containment. For Numbers (encoded as special types of string) all numeric comparison operators are supported (<. >, =, !=, >=, <=). For Vocabularies, which are essentially enumerations of values, the relational operators supported are equality and inequality (=, !=).

- Conditions that refer to complex LOM elements: In this case, the condition is expressed hierarchically using a small tree that contains the complex element structure with its subelements. At the leafs of the tree simple subelements are used to form <attr,op,value> triples as it is the case of simple LOM elements. The interpretation of such complex complex conditions is based on boolean conjunction. For example, in order to express a condition on the complex LOM element classification in order to find objects that have the educational objective verb 'explains', the following condition tree should be constructed: At the root node the tree has a classification_entry node. Under the root, two nodes exist: The first one is the triple <purpose_value,=,educational objective> and the second one is a complex subelement (a subtree) with a taxonPathEntry root

node. Under the taxonPathEntry node, two nodes exist: the first one is the triple <source_string,=,http://somehost/bloomstaxonomy.owl> and the second is again a complex subelement with a taxon_entry node under which there is a triple <id,=,explains>. This example complex condition is satisfied by objects that have a classification element that represent an educational objective with a learning objective verb equal to "explains" taken from the Bloom's taxonomy. A visual representation of this complex condition is given in the following figure:

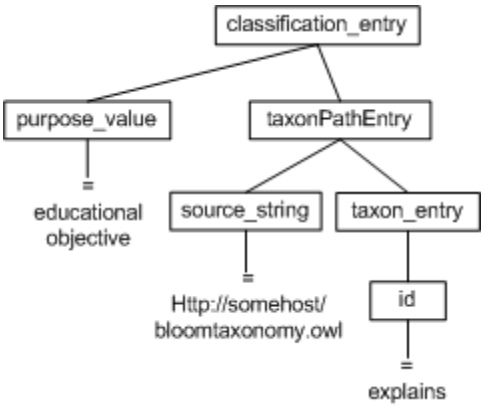


Figure 0.2 An example of a filter condition defined over a complex LOM element

Using Boolean LOM filters, it is possible to express general normal form Boolean expressions on LOM metadata (either conjunctive normal form or disjunctive normal form).

The following figure depicts an example of a Boolean LOM filter that can be used to revieve objects that are

- intended for higher education or their difficulty is medium and
- their educational objective is to explain Iconography and
- they do not have any associated copyrights or costs

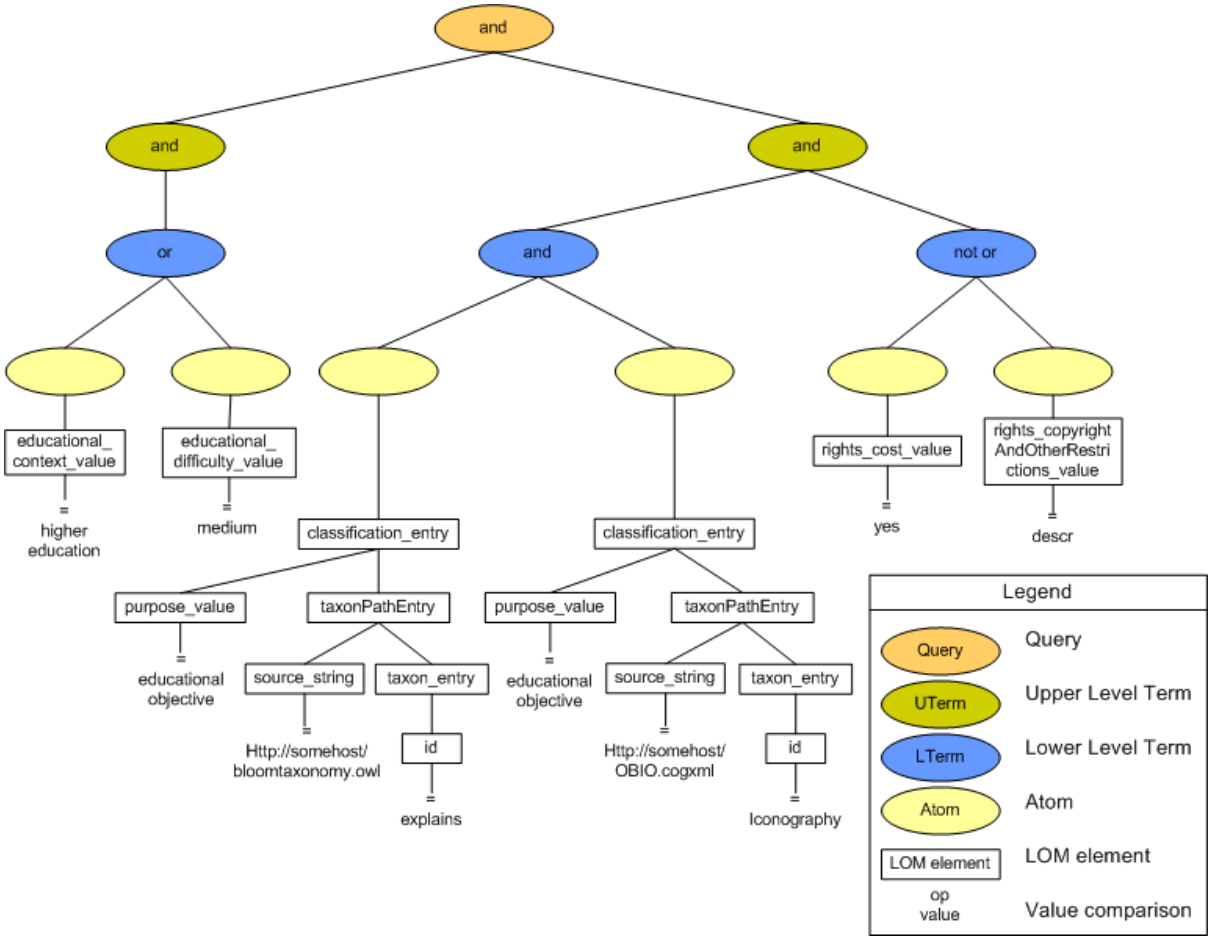


Figure 0.3 Example of a Boolean LOM filter

B. Fuzzy LOM filters

Fuzzy LOM filters are used for similarity searches that produce a ranked list of results. These filters have the same structure as Boolean LOM filters. The only 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).

Evaluation formulae for Fuzzy LOM filters

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∈Q for each Object (LO, CO or AO) o∈O. This function is defined recursively as follows:

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

Let us take, for example the Fuzzy LOM filter f1 depicted in the following figure (note that the only difference from the graphical representation of Boolean LOM filters is the incorporation of the weigh in each UTerm, LTerm and Atom node):

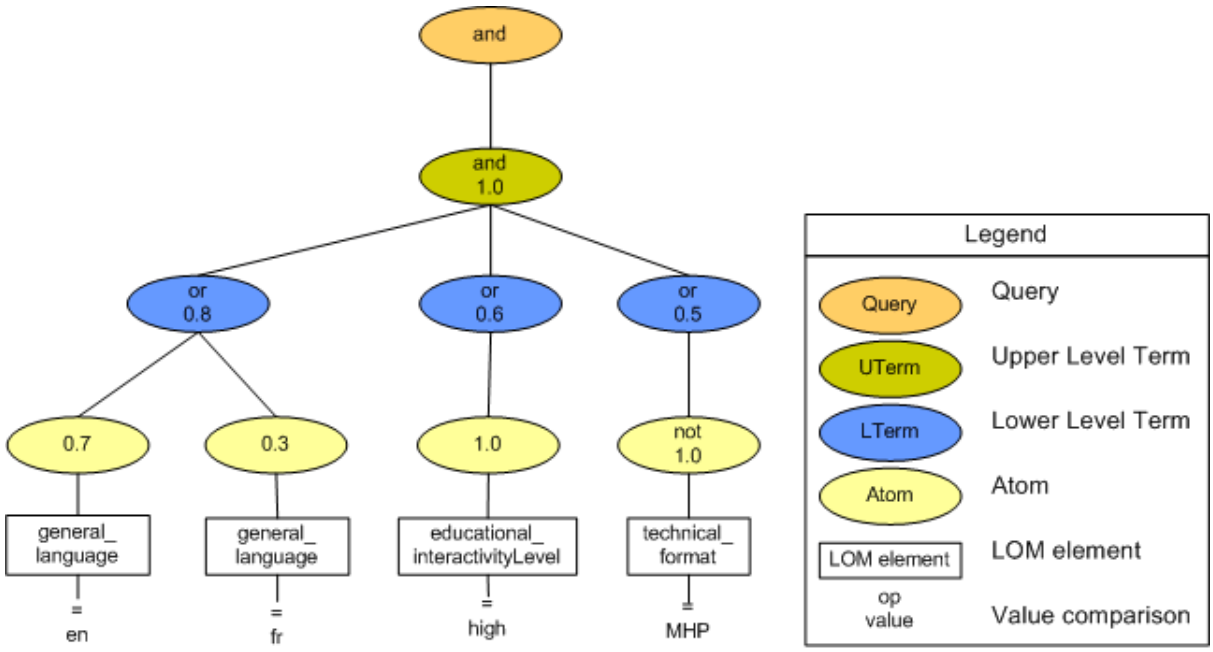


Figure 0.4 Example of a Fuzzy LOM filter

To evaluate this filter for an Object o1, let us assume that the following hold:

F(<general_language,=,en>,o1)=1

F(<general_language,=,fr>,o1)=0

F(<educational_interactivityLevel,=,high>,o1)=1

F(technical_format,=,MHP>,o1)=1

Then, the following equation holds:

$$F(f1,o1) = 1 - \left(\frac{\left(1 - \left(\frac{0.7^p}{0.7^p + 0.3^p} \right)^{\frac{1}{p}} \right)^p \cdot 0.8^p + 0.6^p}{0.8^p + 0.6^p + 0.5^p} \right)^{\frac{1}{p}}$$

For p=1 the above formula gives (approximately) F(f1,o1) =0.4421

For p=2 the above formula gives (approximately) F(f1,o1) =0.54

Note that if we used a Boolean filter q1 instead with the same structure as the above fuzzy filter f1 (exluding term weights, of course) then q1 would be false for o1. Thus, fuzzy filters provide the means to rank objects even when the corresponding Boolean filters are not satisfied. Moreover they provide a rank that discriminates the objects that satisfy a filter.

APPENDIX 3: Domain ontology, learning/assessments objects for personalization example

A. A simple domain ontology about SCORM

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

Table 0.1 A taxonomy describing the SCORM domain

Sharable Content Object Reference Model (SCORM)

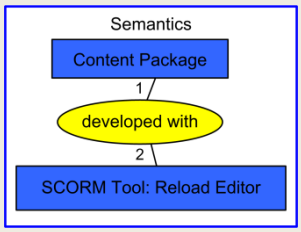
- Content Aggregation Model (CAM)
    - Content Model
        - Content Model Component
            - Asset
            - Sharable Content Object (SCO)
            - Content Organization
            - Metadata
                - Content Aggregation Metadata
                - Content Organization Metadata
                - 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

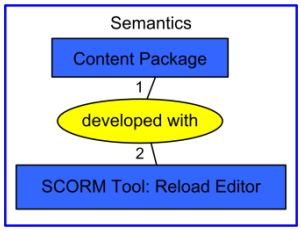
B. Learning Objects

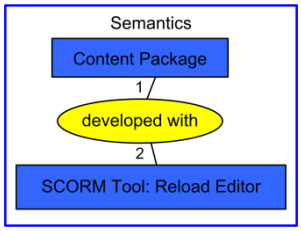
The learning objects that have been developed for the needs of the personalization example of Chapter 3 are presented in the following table.

Table 0.2 Learning Objects for the example of Chapter 3

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	lRT: problem statement iT: active iL: low sD: very high lobv: develop Content Package diff: medium el: Higher Education	
hdc-d351-983	SCORM definition	lRT: narrative text iT: expositive iL: medium sD: low lobv: define SCORM diff: medium el: Higher Education	
mld-j311-927	The SCORM parts	lRT: narrative text iT: expositive iL: medium sD: low lobv: describe SCORM Component diff: medium el: Higher Education	
gkc-n311-439	SCORM content packages	lRT: 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	lRT: simulation iT: expositive iL: very low sD: very low lobv: develop Content Package diff: medium el: Higher Education	
sgd-r514-026	The SCORM eLearning interoperability standard	lRT: narrative text iT: expositive iL: very low sD: very low lobv: define SCORM diff: medium el: Higher Education	
dhv-t315-201	The SCORM Components	lRT: 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	lRT: 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	lRT: narrative text iT: expositive iL: very low sD: very low lobv: define Content Packaging diff: medium el: Higher Education	
tgh-b573-444	SCORM	lRT: narrative text iT: expositive iL: medium sD: medium lobv: define SCORM diff: medium el: Higher Education	
jkg-c511-906	Inside a SCORM Content Package	lRT: 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	lRT: experiment iT: active iL: very low sD: medium lobv: develop Content Package diff: medium el: Higher Education	

APPENDIX 4: Integration of Personalization functionality in a Learning Management System

In this section we describe in detail using use cases the integration of the personalization functionality in a Learning Management System. Moreover, the descriptions of the web services related with the personalization functionality are also presented.

A. Use cases

The use cases developed for the integration of the personalization functionality in are presented in the following figure.

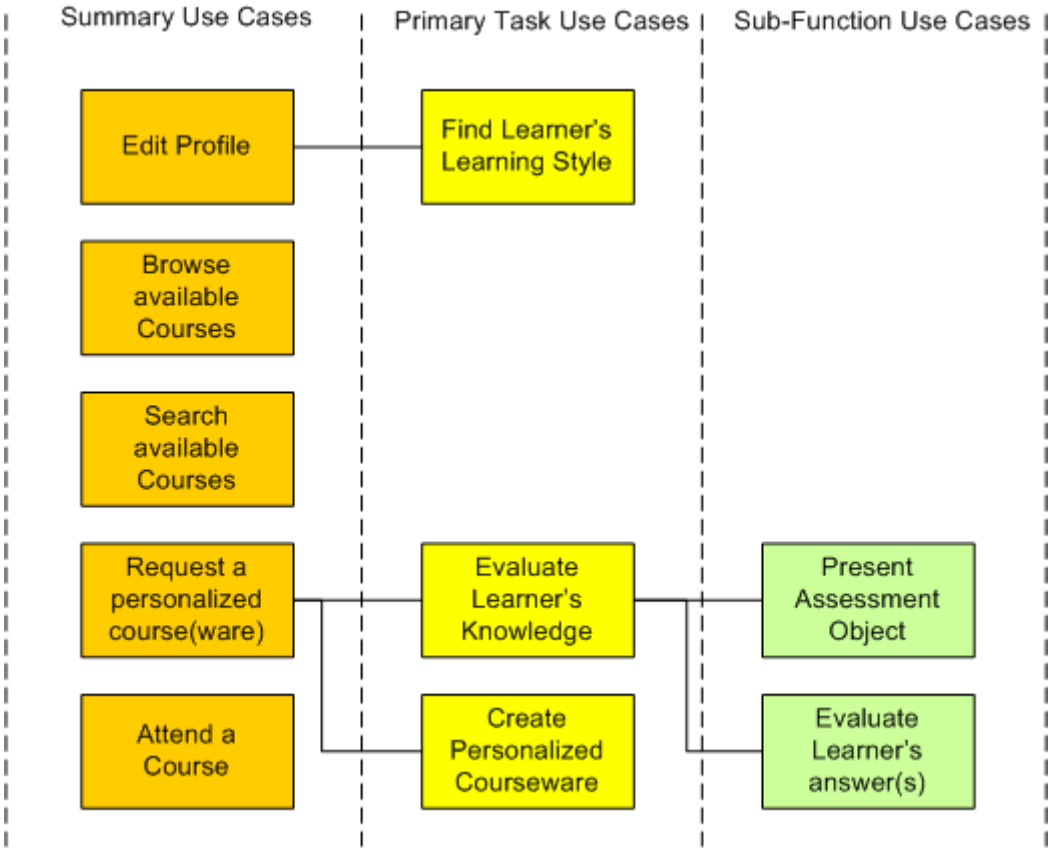


Figure 0.1 Use cases overall scheme

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 *find his/her Learning Style*) 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: *Attend a course* *Search available courses* using specific criteria *Request a personalized course*
EXTENSIONS	**Step**	**Branching Action**
	2	2a1) There are no available courses for the selected domain. The Learner can follow any option of the following: *Search available courses* using specific criteria *Request a personalized course*

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: *Attend a course* *Search available courses* again using specific criteria *Request a personalized course*
EXTENSIONS	**Step**	**Branching Action**
	2	2a1) There are no available courses for the specific criteria. The Learner can follow any option of the following: *Search available courses* again using specific criteria *Request a personalized course*

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.
	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 *evaluate his/her knowledge in the specified domain* 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 *InputParameters_middleware.xml* in Annex) and pass a request to the COE to *create the personalized courseware*. 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 and can now *attend the course* 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 its 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 *type* attribute indicating whether an Assessment ID corresponds to an Assessment Test Object or an Assessment Item Object.
		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.
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 get 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**

B. Services

(i) 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.

Service input:

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 Chapter 3, Section 3.3) and pass a request to the COE to *create the personalized courseware*. 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).

Service output:

Parameter name	Parameter type	Description
createPersExperience Return	string	The id of the generated CO in the Courseware Object Repository.

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.

(ii) 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.

Service input:

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.

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.

(iii) 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 *type* attribute indicating whether an Assessment ID corresponds to an Assessment Test Object or an Assessment Item Object.

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. 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. 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 now be 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 already mentioned, there is no unique way to analyze a Learner Goal to a Learning Objectives hierarchy, and this is highly dependend 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 the following Table. 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. The following table shows the Learning Objectives that currently exist in Learner's profile that are related with the SCORM domain.

Table 0.1 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 0.3.

After the completion of the Assessment by the Learner, the Learning Objectives in his/her profile are updated as illustrated in Table 0.2.

Table 0.2 Updated Learning Objectives and target goals in Learner Profile after previous knowledge testing

Selected Learning Objectives (Learner Goals)	verb	topic	Status (Previous knowledge)	priority
√	comprehend	SCORM	0.3	0.5
	define	SCORM	1.0	0.0
	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	0.0
√	apply	SCORM	0.0	1.0

Table 0.3 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. The process is continued as described in Chapter 3.

APPENDIX 5: 3DE Project Questionnaire

Age:	17-24 □	25-34 □	35-44 □	45-59 □	More than59 □
Gender	F □		M □		
Education	High school □	Degree at University □	Master □	Professional training □	Continuing education □
Field	Technology	Business and Administration	Social & Health & Medicine		
	Humanities	Arts	Agriculture		
	Science	Architecture	Other		
Home Country	Finland □	France □	Italy □	Spain □	
Are you studying now?	In a universitary course □	With continuing education □			
Are you working now?	Yes □	No □			

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.	☐	☐	☐	☐
I like to plan my work properly.	☐	☐	☐	☐
I don't believe in impulsive decisions.	☐	☐	☐	☐
I act spontaneously.	☐	☐	☐	☐
I believe mainly in practical facts.	☐	☐	☐	☐
I like the company of sociable people.	☐	☐	☐	☐
I want to see the connections between theory and practice immediately.	☐	☐	☐	☐
I tend to rely on principles and theories.	☐	☐	☐	☐
I prefer having lots of drafts before making the final version.	☐	☐	☐	☐
I usually say immediately what I think in order to achieve results quickly.	☐	☐	☐	☐
I don't comment before I've thought things through.	☐	☐	☐	☐
I get bored with routines.	☐	☐	☐	☐
I want to consider all information carefully before making any decisions.	☐	☐	☐	☐
I try to consider things in their logical context.	☐	☐	☐	☐
I find new experiences interesting.	☐	☐	☐	☐
I'm always a very practical person.	☐	☐	☐	☐
I work out my thoughts before I express them.	☐	☐	☐	☐
I like to take several points of view into consideration before deciding my own.	☐	☐	☐	☐

Straight action is more typical for me than careful.	☐	☐	☐	☐
I tend to produce innovative ideas.	☐	☐	☐	☐
I tend to get straight to the point in the meetings.	☐	☐	☐	☐
I don't act without proper planning.	☐	☐	☐	☐
I like to work in detail before coming to a conclusion.	☐	☐	☐	☐
I always prefer a systematic way of working.	☐	☐	☐	☐
I work analytically when solving problems.	☐	☐	☐	☐
I don't hide my feelings.	☐	☐	☐	☐
I work effectively to see the practical results.	☐	☐	☐	☐
I avoid making hasty conclusions.	☐	☐	☐	☐
I'm interested in putting ideas into practice.	☐	☐	☐	☐
I tend to organise my thoughts well.	☐	☐	☐	☐
I seek theoretical principles behind things and events.	☐	☐	☐	☐
I am usually the innovative person in the social situations.	☐	☐	☐	☐
I like talking more than listening.	☐	☐	☐	☐
Scientifically proved theories interest me.	☐	☐	☐	☐
I find it difficult to be spontaneous.	☐	☐	☐	☐
I am open to use any efficient method to reach results.	☐	☐	☐	☐

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 availed 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 advantage, 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 6: Learning Objects and Learning Designs for the "Learning LOGOS through LOGOS" course

A. Learning Objects developed to support all learning styles according to Honey and Mumford

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)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Authoring Studio
Ontologies (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: medium
	sD: very high
	lobv: define Ontology
The Ontology Management Tool (semantic density: very high)	lRT: 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	lRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Ontology Management Tool -OMT
Media Objects (MOs) (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Media Object - MO
The Media Server (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Media Server
Creating Media Objects using Media Server – Problem Statement	lRT: problem statement
	iT: active
	iL: very high

	sD: very high
	lobv: use Media Server
Digital Objects (DOs) (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Digital Object - DO
The Content Description Tool (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Content Description Tool - CDT
Creating Digital Objects using Content Description Tool (CDT) – Problem Statement	lRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Media Server
Learning Objects (LOs) (semantic density: very high)	lRT: 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)	lRT: 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	lRT: problem statement
	iT: active
	iL: medium
	sD: very high
	lobv: use Description Tool for Learning Objects - DTLO
Courseware Objects (COs) (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Courseware Object - CO
The Courseware Objects Editor (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Courseware Object Editor - COE
Creating Courseware Objects using Courseware Objects Editor	lRT: problem statement

(COE) - Problem Statement	iT: active
	iL: very high
	sD: very high
	lobv: use Courseware Object Editor - COE
Assessment Objects (AOs) (semantic density: very high)	lRT: 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	lRT: 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	lRT: problem statement
	iT: active
	iL: very high
	sD: very high
	lobv: use Courseware Object Editor – COE
Learning Designs (LDs) (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Learning Design
The Learning Designs Editor (semantic density: very high)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very high
	lobv: define Learning Design Editor – LDE
Creating Learning Designs using Learning Designs Editor (LDE)	lRT: problem statement
	iT: active
	iL: very high
	sD: very high
	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
Ontology Management Tool (OMT) Tutorial	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Ontology Management Tool (OMT) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Media Server User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Content Description Tool (CDT) Tutorial	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Media Server
Content Description Tool (CDT) User Manual	lRT: 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)	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low

	lobv: use Description Tool for Learning Objects - DTLO
Courseware Object Editor (COE) User Manual	lRT: 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)	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Description Tool for Learning Objects (DTLO) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Courseware Objects Editor (COE) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Courseware Object Editor – COE
Learning Designs Editor (LDE) Tutorial	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use 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: very low)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe LOGOS Project
The LOGOS Platform (semantic density: vlow)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe LOGOS Platform
LOGOS Objects (semantic density: very low)	lRT: narrative text

	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Object
Ontologies (semantic density: very low)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Ontology
The Ontology Management Tool (semantic density: very low) Containing Ontology Management Tool DO and Process DO	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Ontology Management Tool -OMT
Ontology Management Tool (OMT) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Ontology Management Tool -OMT
Media Objects (MOs) (semantic density: very low)	lRT: 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	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Media Server
Media Server User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Digital Objects (DOs) (semantic density: very low)	lRT: 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	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low

	lobv: describe Content Description Tool - CDT
Content Description Tool (CDT) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Media Server
Learning Objects (LOs) (semantic density: very low)	lRT: 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) Containing The Description Tool for Learning Objects (semantic density: very high) and Process LO	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Description Tool for Learning Objects - DTLO
Description Tool for Learning Objects (DTLO) User Manual	lRT: 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)	lRT: 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	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Courseware Object Editor - COE
Courseware Object Editor (COE) User Manual	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: use Courseware Object Editor - COE
Assessment Objects (AOs) (semantic density: very low)	lRT: narrative text
	iT: expositive
	iL: very low
	sD: very low
	lobv: describe Assessment

	Object - AO
Description Tool for Learning Objects (DTLO) User Manual	lRT: 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)	lRT: 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	lRT: 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	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Media Server
Description Tool for Learning Objects (DTLO) Walkthrough for Learning Objects (LOs)	lRT: 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)	lRT: 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)	lRT: 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)	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Description Tool for Learning Objects – DTLO
Courseware Objects Editor (COE) Cognitive Walkthrough	lRT: experiment

	iT: active
	iL: very low
	sD: low
	lobv: use Courseware Object Editor – COE
Learning Designs Editor (LDE) Cognitive Walkthrough	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Learning Design Editor - LDE
Learning Designs Editor (LDE) Tutorial	lRT: simulation
	iT: expositive
	iL: low
	sD: very low
	lobv: use Learning Design Editor - LDE

B. Learning Designs to support 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). 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.

(i) 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 0.1 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	lRT: 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	lRT: 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?	lRT: narrative text iT: expositive iL: medium sD: very high lobv: define Ontology	Ontologies (semantic density: very high)
2b	What is the Ontology Management Tool?	lRT: 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	lRT: 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?	lRT: 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?	lRT: narrative text iT: expositive iL: very low sD: very high lobv: define Media Server	The Media Server (semantic density: very high)
3c	Using Media Server to create and manage Media Objects	lRT: problem statement iT: active iL: very high sD: very high	Creating Media Objects using Media Server – Problem Statement

		lobv: use Media Server	
4	Developing Digital Objects	lobv: create Digital Object - DO	-
4a	What is a Digital Object?	lRT: 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?	lRT: 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	lRT: 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?	lRT: 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?	lRT: 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	lRT: 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?	lRT: 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?	lRT: narrative text iT: expositive iL: very low sD: very high lobv: define Courseware Object Editor - COE	The Courseware Objects Editor (semantic density: very high)
6c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) – Problem Statement	lRT: 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?	lRT: 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	lRT: 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	lRT: 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?	lRT: 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?	lRT: 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	lRT: 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)

(ii) 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 0.2 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	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Project	The LOGOS Project (semantic density: medium)
1b	The LOGOS Platform	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Platform	The LOGOS Platform (semantic density: medium)
1c	LOGOS Objects	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe Object	LOGOS Objects (semantic density: medium)
1d	The LOGOS Authoring Studio	lRT: 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	lRT: 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	lRT: narrative text iT: expositive	Ontology Management Tool (OMT) User Manual

	manage Ontologies – Manual	iL: very low sD: very low 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 – Tutorial	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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 Courseware Objects (COs) - Manual	lRT: 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	Using Description Tool for Learning Objects (DTLO) to	lRT: simulation iT: expositive	Description Tool for Learning Objects (DTLO)

	create and manage Assessment Item Objects (AIOs) – Tutorial	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	Tutorial for Assessment Item Objects (AIOs)
7b	Using Description Tool for Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Manual	lRT: 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	lRT: 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	lRT: 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	lRT: 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 manage Learning Designs (LDs) - Manual	lRT: 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

(iii) 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 0.3 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	lRT: 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	lRT: narrative text iT: expositive iL: very low sD: very low lobv: describe LOGOS Platform	The LOGOS Platform (semantic density: vlow)
1c	LOGOS Objects	lRT: 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	lRT: narrative text iT: expositive	Ontologies (semantic density: very low)

		iL: very low sD: very low lobv: describe Ontology	
2b	The Ontology Management Tool	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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)	lRT: 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	lRT: 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	lRT: 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)	lRT: narrative text iT: expositive	Learning Objects (LOs) (semantic density: very

		iL: very low sD: very low lobv: describe Digital Object - DO	low)
5b	The Description Tool for Learning Objects	lRT: 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	lRT: 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)	lRT: 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	lRT: 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	lRT: 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)	lRT: 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 Learning Objects (DTLO) to create and manage Assessment Item Objects (AIOs) – Manual	lRT: 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 →	Description Tool for Learning Objects (DTLO) User Manual

		Manual	
7c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) – Manual	lRT: 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)	lRT: 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	lRT: 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	lRT: 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

(iv) 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 applicaple 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 0.4 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	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Project	The LOGOS Project (semantic density: medium)
1b	The LOGOS Platform	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe LOGOS Platform	The LOGOS Platform (semantic density: medium)
1c	LOGOS Objects	lRT: narrative text iT: expositive iL: very low sD: medium lobv: describe Object	LOGOS Objects (semantic density: medium)
1d	The LOGOS Authoring Studio	lRT: 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	lRT: 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	lRT: simulation iT: expositive iL: low sD: very low lobv: use Ontology Management Tool -OMT	Ontology Management Tool (OMT) Tutorial
3	Developing Media Objects	lobv: create Media Object - MO	-
3a	Using Media Server to create and Manage Media Objects - Experiment	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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	lRT: 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 (AIOs) – Experiment	lRT: experiment iT: active iL: very low sD: low lobv: use Description Tool for Learning Objects – DTLO Semantics: Assessment Item Object – AIO →developed with 1 → Description Tool for Learning Objects – DTLO	Description Tool for Learning Objects (DTLO) Walkthrough for Assessment Item Objects (AIOs)
7b	Using Description Tool for Learning Objects (DTLO) to create and manage	lRT: simulation iT: expositive iL: low	Description Tool for Learning Objects (DTLO) Tutorial for Assessment

	Assessment Item Objects (AIOs) – Tutorial	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	Item Objects (AIOs)
7c	Using Courseware Objects Editor (COE) to create and manage Courseware Objects (COs) - Experiment	lRT: 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	lRT: 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	lRT: 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	lRT: 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