Supporting Personalized Learning Experiences on top of Multimedia Digital Libraries

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***Abstract*—** In this paper are provided solutions to support the construction of eLearning applications on top of Digital Libraries in order to be able for eLearning applications to effectively exploit the wealth of content residing in Digital Libraries**.** **T**he provision of efficient personalization services to Learners beyond "one size fits all" solutions is considered as a necessity to cope with this problem and generally with the overwhelming amount of available learning materials existing in Digital Libraries. For that reason the framework provides the necessary methodology, models and mechanisms for the dynamic creation of pedagogically-sound personalized learning experiences from digital objects through learning objects combined according to learning scenarios in courses, curricula and demonstrators, using authoring tools of Learning and Content Management Systems, taking into account the variety of the Learners and their individual needs. The problem of interoperability between digital libraries and eLearning applications is a complex and multi-level one and can be seen from many points of view. From a *standards point of view*, it can be seen as a stack of conceptual layers where each one is built on top of the previous one. From an object point of view an important step is the path for transformation of digital object into learning object. From an *infrastructures point of view* - similar to the procedure followed in traditional learning environments. From the pedagogical point of view two main pedagogical styles are considered. As a result a generic interoperability/repurposing framework and a service-oriented architecture where learning experiences are dynamically constructed taking into account user profiles and pedagogical templates is proposed.

***Keywords*—**Multimedia Digital Libraries, personalized learning, learning objects, service-oriented architecture, learning experiences, interoperability/repurposing framework,

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I. Introduction

NOWADAYS, the rapid development of technology highlighted the need for continuous training and acquiring new skills. In this society Information and Communication Technology is both a catalyst and a necessity. Consequently, there has been a rapidly growing interest in the provision of lifelong learning opportunities both in workplace and home environments. In this context, the traditional forms of instruction are many times not adequate due to the natural limitations (time and space) they imply and their high cost. Without overriding them, the traditional forms of instruction have been enriched with new approaches that have a strong technological underlying base[13]. eLearning infrastructures have been developed that are based on specialized information systems that allow for the development, management and provision of advanced instructional services anytime, anywhere.

On the other hand, libraries have been always being an important source of learning resources. In a digital library, knowledge providing content comes in a variety of sizes and formats. 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.

Digital libraries' and eLearning Applications' roles are complementary and if used together they could efficiently support learning purposes. eLearning applications would be immensely more valuable if they could effectively use the wealth of information that exists in Digital Libraries. However, the current situation is quite different from this theoretically logical harmonic cooperation:

- A lack of effective support of digital library applications for learning purposes is observed
- Applications are well known to be long living, and typically they have longer life than systems, so they tend to create their own standards, and support infrastructures based on those standards. Digital Libraries and their standards have been developed independently from eLearning

applications and their standards
- eLearning applications as independent infrastructures do not interoperate effectively and efficiently with digital libraries
- Complex and multilevel problem.

It is crucial to bridge the interoperability gap between digital libraries and eLearning applications in order to enable the construction of eLearning applications that easily exploit digital library contents. This paper provides solutions to support the construction of eLearning applications on top of Digital Libraries in order to be able for eLearning applications to effectively exploit the wealth of content residing in Digital Libraries.

A framework and a service-oriented architecture to address this problem are proposed. This framework goes beyond the domain of eLearning and is able to accommodate approaches that aim at repurposing and use the underlying digital library content in other domains as well such as eScience, eResearch etc. That means that this framework can be easily applied in other types of applications, since it supports multiple contexts and views of the digital objects of a digital library. Using the approach proposed in this framework, the construction of audiovisual learning objects is possible, containing information about their educational use through learning object metadata, while in parallel retaining their audiovisual characteristics described using audiovisual standards (e.g. MPEG7). It has to address how the audiovisual learning objects are afterwards combined or organized in meaningful structures to create learning experiences that are delivered through LMSs to Learners to cover their individual needs.

Moreover, the provision of efficient personalization services to Learners beyond "one size fits all" solutions is considered as a necessity to cope with this problem and generally with the overwhelming amount of available learning material existing in Digital Libraries. For that reason the framework provides the necessary methodology, models and mechanisms for the dynamic creation of pedagogically-sound personalized learning experiences from digital objects through learning objects combined according to learning scenarios in courses, curricula and demonstrators, using authoring tools of Learning and Content Management Systems, taking into account the variety of the Learners and their individual needs.

II. Illustrating the Content Assembly Concept using the Learnativity Content Model

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

The Digital Libraries domain is very complex and highly multidisciplinary [3]. 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) [3]. 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. Neuhold and Niederée [9] 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".

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, while Learning Management System (LMS) focuses on delivering, tracking and managing training/education. LMS cannot create and manipulate courses, reuse the content of one course to build another. We could say that the roles of these systems are complementary and they must be eLearning standards compliant.

Traditionally, learning is organized in lessons and courses covering predefined objectives.

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 [12]. 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 to the LEGO metaphor [4]. The idea is to build small, self-contained, reusable components that can be aggregated with other components. They 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). According to [10] **learning object** 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).

For the purposes of the paper the Learnativity Content Model [11] is used, illustrating the concept of assembling content into higher-level objects. Learning objects are assembled into higher-order collections such as courses and curricula. This model is very useful for describing granularity and granularity is very useful to achieving reusability.

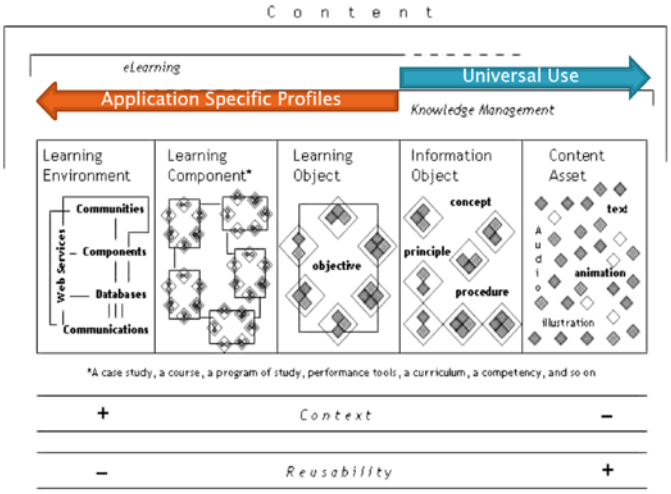

Fig. 1 Learnativity Content Model [11]

The basic components of the Learnativity content model are the following:

- **Content Asset**: Content Assets include raw media such as images, text snippets, audio clips, applets, etc.
- **Information Object**: A text passage, Web page(s), applet, etc. that focus on a single piece of information. It might explain a concept, illustrate a principle, or describe a process. exercises are often considered to be information objects.
- **Learning Object**: 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 services 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).

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.

In the broad sense a learning object is a digital object, as well as a cultural object is a digital object. Although learning objects are information objects they are differentiated by their intent and design:

The intent of a learning object is to facilitate learning, while information objects are designed to be a reference, and not necessarily for the purpose of retaining skills or concepts by the user [8].

III. The Multilevel Problem of Interoperability between Digital Libraries and (eLearning) Applications

The problem of interoperability between digital libraries and eLearning applications is a complex and multi-level one and can be seen from many points of view.

From a *standards point of view*, it can be seen as a stack of conceptual layers where each one is built on top of the previous one. There are different data representations, objects, concepts, domains, contexts and meta-contexts in the layer stack that should be efficiently managed in a standard way. Each metadata model is shown as a vertical bar on this stack to cover a specific region that represents the parts that the model tries to capture and describe in a standard way. If a different metadata model is put besides this stack, one may identify gaps and intersection regions so that it is apparent where the interoperability problems among these models occur. Of course, interoperability problems exist also in the overlapping areas. But in these areas solving the problem of interoperability is easier and can be solved with standard methods (e.g. by means of mappings). The major problems arise in the areas with no overlaps between the two metadata standards.

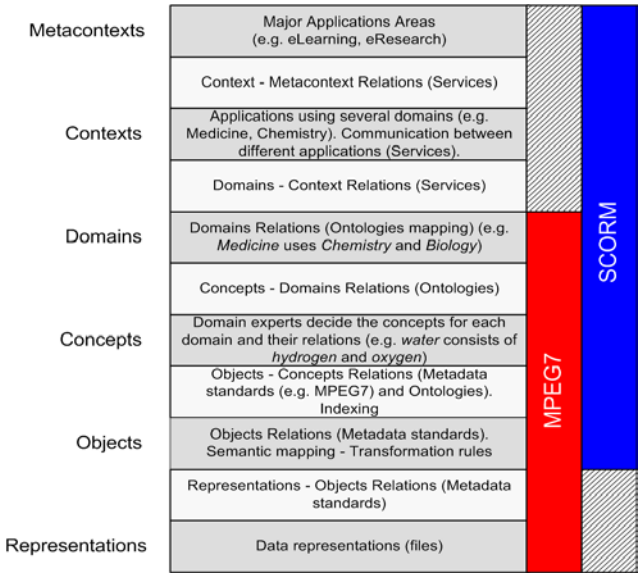

Fig. 2 Interoperability from standards point of view

From an object point of view an important step is the path for transformation of digital object into learning object. A digital object becomes a learning object when it is designed to be used by itself or in combination with other media objects to facilitate or promote learning having clear pedagogical purpose (learning outcome/objective) that is appropriately linked to the object through learning metadata and the right granularity and content for the target pedagogical purpose. Transforming digital objects to learning objects is not a straightforward and a one-to-one mapping process. Use determines whether a digital object becomes a learning object, but we cannot predict all possible educational uses of a digital

object or whether we should use a part of it, or to combine it with other objects to serve all of them. The target educational use of a digital object is connected straight fold with its appropriate granularity and content. Finally, learning metadata is important in order for a digital object to be exploited by eLearning applications, but describing a digital object without a clear educational context is not possible.

From an *infrastructures point of view* the authoring procedure that is currently followed in eLearning environments for the creation of courseware is similar to the procedure followed in traditional learning environments.

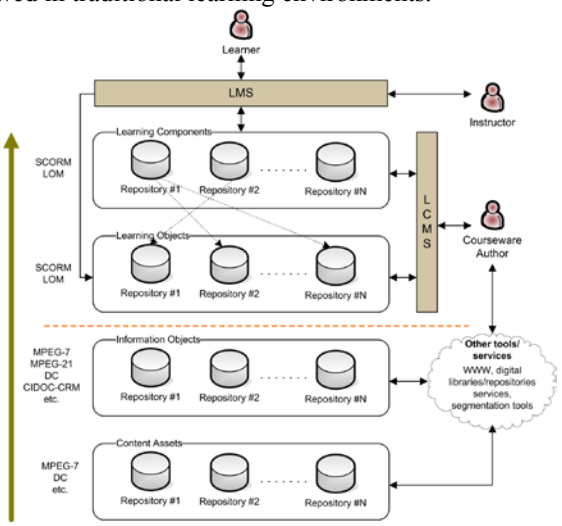

Fig. 3 An infrastructures point of view

The first step for the author is to define a number of learning objectives that should be fulfilled in order for the target objective (learning goal) to be satisfied. Thereafter, he is trying to find appropriate learning content to create learning units (LOs) to support these objectives. An Author, for the creation of learning objects through an LCMS either discovers and reuses existing learning object, which to repurposes depending on the target educational context, or starts the creation of a new one.

In both cases is needed appropriate digital objects (Content Assets and/or Information Objects in terms of Learnativity Content Model) to be found. However, in order for these digital objects to be accessible from the LCMS, they should be represented and described according to eLearning standards (e.g. SCORM, LOM) and stored in a learning objects/assets repository.

An important aspect is the pedagogical point of view. Two main pedagogical styles are considered Kolb's [7] and Honey&Mumford's [5]. In the model developed by Kolb, learning styles are measured on two perpendicular axes (continuums):

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

Activity-oriented learners are with high interactivity level for activists, who are more motivated by experimentation and challenging tasks.

Example-oriented learners are reflectors who tend to collect and analyze data before taking action.

Exercise-oriented learners are pragmatists, keen on trying out ideas, theories and techniques.

Theory-oriented learners are theorists, given the chance to explore and discover concepts in more abstract ways.

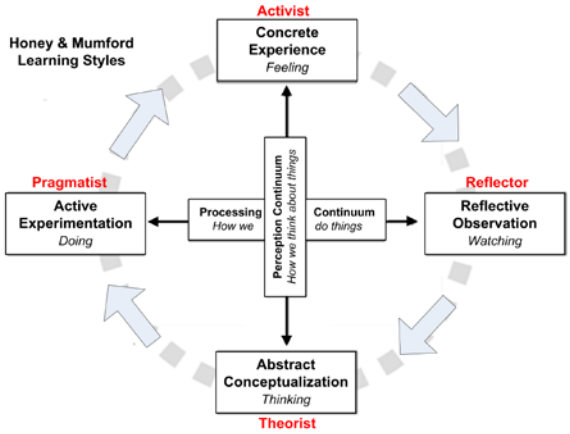

Fig. 4 Kolb vs. Honey&Mumford pedagogical styles

IV. Envisioned Scenario

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

In order to support this scenario, it is of great importance to provide the ability to re-purpose or enable others to locate and re-purpose digital objects in different (educational) contexts. "Repurposing" or "reauthoring" is the process of adaptation of a given audiovisual resource in order to produce a new version of it which may be composed of parts coming from different source documents. A repurposed or re-authored version should correspond better to the expectations, needs and interests of a target user group. The re-authoring process is a multi-step and complicated activity that is not currently supported by appropriate technologies. As a result, both content providers and content users are not able to exploit effectively the available learning resources residing in multimedia digital libraries [13] in various contextualized uses and especially in formal and informal learning scenarios.

In the envisioned scenario illustrated in figure 3 the red borderline of the conceptual architecture has been removed. In this scenario eLearning Applications are able to access and repurpose digital content at each level starting from content assets using common interfaces/services. The repurposing process is done at each level using common repurposing tools, access and management services to produce objects of the next

level. An important feature of this scenario is personalization through dynamic creation of Learning Components from audio-visual learning objects to satisfy the needs of different learners (learning style, educational level, prior knowledge etc.). This functionality can be used both by Learners and Courseware Authors through an LMS and LCMS respectively for the creation of personalized learning experiences. Courseware Authors can use this functionality to semi-automatically create their courses to match a specific learner profile or stereotype.

To implement the above scenario we should support both multiple (educational) contexts views of digital objects and pedagogy-driven personalized learning experiences.

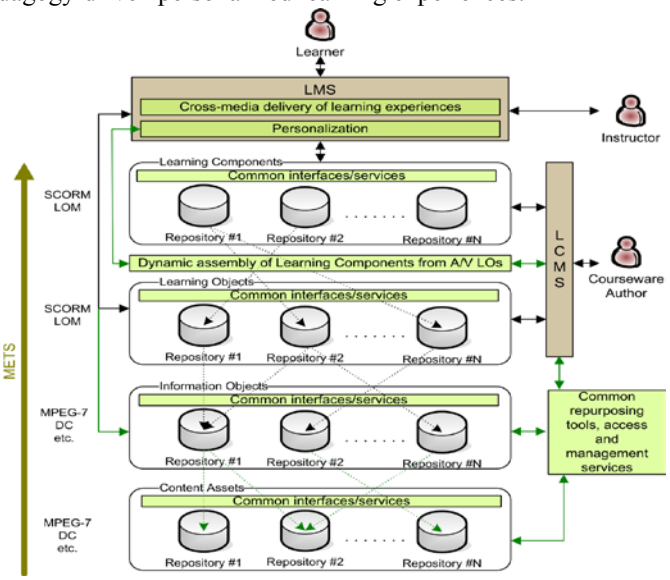

Fig. 5 The envisaged scenario

The envisaged scenario supports the construction of high-quality learning experiences, assembled in a number of different ways from audiovisual objects to support the needs of different Learners and delivered in the form of learning experiences through a number of different channels eLearning Applications, able to access and repurpose digital content at each level, starting from content assets.

The repurposing process is done at each level using common repurposing tools, access and management services to produce objects of the next level. Personalization through dynamic creation of Learning Components from audio-visual learning objects to satisfy the needs of different learners (used by Learners, Courseware Authors).

The final goal is supporting Personalized Learning Experiences on top of Multimedia Digital Libraries through effective exploitation of the wealth of content in Multimedia Digital Libraries from eLearning Applications.

V. Architecture

The envisioned scenario was achieved through the development of a service-oriented Framework and Architecture for supporting multiple (educational) contexts views and re-purposing of (audiovisual) digital objects, supporting pedagogy-driven personalized learning experiences on top of Multimedia Digital Libraries.

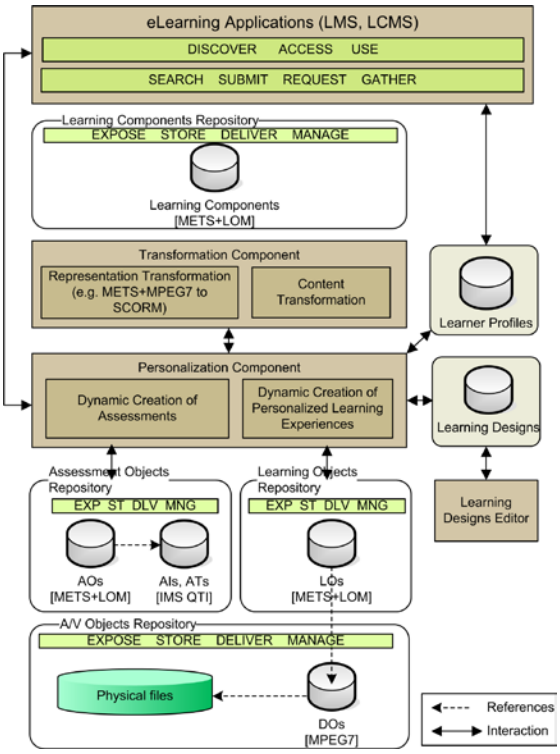

Fig. 6 The final architecture that was realized

The architecture presented here addresses the identified interoperability problems in a layered architecture where eLearning (and other) applications are built on top of audiovisual digital libraries and utilize their content. This architecture [1]; [2] illustrated in Figure 6 consists of layered repositories supporting the gradual creation of learning experiences starting from existing content residing at audiovisual archives and offers a generic framework for the dynamic creation of personalized learning experiences using reusable audiovisual learning objects. It is service-oriented and conforms to the IMS Digital Repositories Interoperability (IMS DRI) Specification [6] 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. These functions should be implementable across services to enable them to present a common interface.

Figure 6 illustrates the architecture components, which are the following:

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

Objects that are assembled to teach a single learning objective.

- **Assessment Objects (AOs)** that are used to assess the satisfaction of certain learning objectives. Assessment Objects could be simple questions (Assessment Items) or complex questionnaires consisting of Assessment Items (Assessment Tests). AOs are also described with educational metadata.
- **Learning Components (LCs)** corresponding to learning experiences utilizing the underlying Learning Objects and Assessment Objects and that can be delivered using different delivery devices. They are hierarchies of activities supported with LOs or AOs and they are described with educational metadata and possibly sequencing and navigation metadata.

- eLearning Applications (Software Agents in terms of IMS DRI, like Learning Content Management Systems, Learning Management Systems etc.) that discover, access and use the content of the A/V content of the digital library through appropriate services (resource utilizers). Authoring tools for the authoring of the above types of objects as well as Learning Management Systems for the delivery of learning experiences to Learners are considered as applications. Learning Management Systems in this framework include components encapsulating functionality to adapt the learning material to individual user needs and context as well as to track user's progress and update the user related information represented in Learner Profiles.
- The Personalization Component residing between the Learning Objects Repository level and the Learning Components Repository level and used for the **Dynamic Creation of Personalized Learning Experiences** according to specific learning needs expressed in Learner Profiles and using a set of abstract training scenarios (**Learning Designs**) constructed using a tool named **Learning Design Editor**. This service can be exploited both by Learners as learning experiences and by courseware authors providing them a semi-automatic method for the creation of courseware. Before transforming the resulted learning experience to a SCORM package, it is stored as a Learning Component being ready and available in an interoperable way for later requests. The Personalization Component encapsulates functionality for the **Dynamic Creation of Assessments** from Assessment Objects in order to "measure" the previous knowledge of the Learner and update his/her Learner Profile.
- The Transformation Component, which is responsible for the transformation of the objects' METS-based descriptions to SCORM Content Packages. This includes not only simple transformation from METS XML file to SCORM manifest file, but also the construction of the whole SCORM package (PIF). Moreover, the type of the underlying physical files is taken into account (from MPEG7 descriptions), as well as the requirements of the delivery channel and, if needed, intermediate html pages are constructed with links to these files (e.g. in case of video files) and appropriate content transformations are performed.

VI. Conclusions

In this paper we provided solutions to support the construction of eLearning applications on top of Digital Libraries in order to be able for eLearning applications to effectively exploit the wealth of content residing in Digital Libraries. Towards this end, we proposed a generic interoperability/repurposing framework and a service-oriented architecture where learning experiences are dynamically constructed taking into account user profiles and pedagogical templates.

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

Implemented in LOGOS "Knowledge-on-Demand for Ubiquitous Learning" (IST-4-027451) Project (**common project of TUC with IMI-BAS, 2006–2008**) [1], [2]

Applied in LdV/ToI QONIAon project (**common project of TUC and LT-BAS, 2013-2015**)

VII. Some base definitions used in the paper.

The proposed definition to be used for learning object is a collection of digital multimedia materials (objects) — pictures, documents, simulations — coupled with a clear and measurable learning objective.

The proposed definition to be used for learning scenario is a priori description of a learning situation, independently of the underlying pedagogical approach. It describes its organization with the goal of ensuring the appropriation of a precise set of knowledge, competences or skills. It may specify roles, activities and required resources, tools and services.

The proposed definition to be used for lesson plan is instructor's road map of what students need to learn and how it will be done effectively during the class time.

Demonstrator is realized learning scenario, based on appropriate lesson plan(s), consisting of learning objects, elaborated using appropriate for the target auditory pedagogical styles. It can be Skill-Based, Problem-Based, Issue-Based, Speculative, or Gaming.

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