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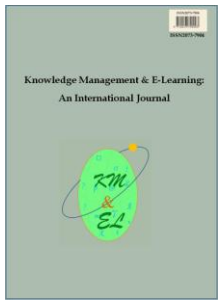

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Learning object repositories as knowledge management systems

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Abstract: Over the past years, a number of international initiatives that recognize the importance of sharing and reusing digital educational resources among educational communities through the use of Learning Object Repositories (LORs) have emerged. Typically, these initiatives focus on collecting digital educational resources that are offered by their creators for open access and potential reuse. Nevertheless, most of the existing LORs are designed more as digital repositories, rather than as Knowledge Management Systems (KMS). By exploiting KMSs functionalities in LORs would bare the potential to support the organization and sharing of educational communities' explicit knowledge (depicted in digital educational resources constructed by teachers and/or instructional designers) and tacit knowledge (depicted in teachers' and students' experiences and interactions of using digital educational resources available in LORs). Within this context, in this paper we study the design and the implementation of fourteen operating LORs from the KMSs' perspective, so as to identify additional functionalities that can support the management of educational communities' explicit and tacit knowledge. Thus, we propose a list of essential LORs' functionalities, which aim to facilitate the organization and sharing of educational communities' knowledge. Finally, we present the added value of these functionalities by identifying their importance towards addressing the current demands of web-facilitated educational communities, as well as the knowledge management activities that they execute.

Keywords: Learning objects; Learning object repositories; Knowledge for educational practice; Knowledge of educational practice; Knowledge management systems

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1. Introduction

Today it is commonly argued that, digital educational resources generated by teachers and by students, as well as by teacher-to-students and students-to-students interactions during day-to-day school activities constitute core knowledge assets of educational communities (Chen, Chen, & Kinshuk, 2009; Carroll, Rosson, Dunlap, & Isenhour, 2005; Hsu & Ou Yang, 2008), educational communities can be defined as: "*groups of people who share their common interest about education*" (Wenger, McDermott, & Synder, 2002, p. 2). Within educational communities, digital educational resources are worthy to be organized, managed, shared and reused effectively (Hsu & Ou Yang, 2008). For this purpose, a number of international initiatives have emerged recently and they have recognized the importance of sharing and reusing digital educational resources among educational communities typically represented in the form of Learning Objects (LOs) (McGreal, 2004; UNESCO, 2002). Such a leading initiative is the Open Educational Resources (OER) movement which aims to create and share open educational resources that are freely available online for everyone to use and explore (Caswell, Henson, Jensen, & Wiley, 2008).

Most of the above mentioned initiatives provide systems and services that aim to support the web-based management of LOs. A particular category of those systems is the Learning Objects Repositories (LORs), which are developed to facilitate search, retrieval and access to LOs (Geser, 2007). Even though, this is indeed the main general scope for the development of LORs, existing implementations of LORs are not necessarily focused on addressing common issues, but rather each of them produces a reflection of their own perception of the problem of managing digital educational resources on the web, thus

resulting to different LORs implementations (McGreal, 2004; McGreal, 2008). This is actually a drawback for the design and development of future LORs, since there is not a common list of LORs functionalities, which can be implemented towards addressing the problem of managing digital educational resources on the web.

Furthermore, most of the existing LORs are designed as digital repositories of educational resources providing functionalities only for the organization and sharing of educational communities' explicit knowledge (typically depicted in digital educational resources constructed by teachers and/or instructional designers), whereas functionalities for the organization and sharing of educational communities' tacit knowledge (typically depicted in teachers' and students' experiences and interactions using digital educational resources available in LORs) are very limited. However, both aforementioned knowledge types are very important to be managed, shared and reused effectively among educational community members (McLaughlin & Talbert, 2006).

On the other hand, Knowledge Management Systems (KMSs) have been used to facilitate the acquisition, fostering and reuse of the different types of knowledge created within organizations (Holsapple, 2003). Furthermore, considering the potential of user-generated digital content in Web 2.0 communities, knowledge management is recently revisited (Allen, 2008; Lin, Lin, & Huang, 2008; Hafeez & Alghatas, 2007), since new knowledge is often developed by small, informal and self-organized networks of practitioners (Kirchner, Razmerita, & Nabeth, 2009; Levy, 2009). As a result, knowledge from specific disciplines is no longer provided and assesses solely by domain experts, but also by peers and by using Web 2.0 tools. Within this context, in this paper we study the design and the implementation of existing LORs from the KMSs perspective, so as to identify additional functionalities that can support organizing and sharing of the different types of educational communities' knowledge.

2. Learning objects management in learning objects repositories

LOs are a common format for developing and sharing digital educational resources in the field of technology-enhanced learning and they can be defined as: "*any type of digital resource that can be reused to support learning*" (Wiley, 2002, p.346). LORs are systems that aim to support the web-based management of LOs (McGreal, 2008). Within the rich literature on this subject, there are a number of studies that define LORs and examine their characteristics and functionalities (Higgs, Meredith, & Hand, 2003; IMS, 2003; McGreal, 2004; Lehman, 2007; Ochoa & Duval, 2008; Tzikopoulos, Manouselis, & Vuorikari, 2009). This has resulted in a wide variety of definitions about LORs, which can be summarized in Table 1.

As we can notice from Table 1, Higgs, Meredith, and Hand (2003) consider LORs as database systems that provide functionalities, such as search and retrieval to facilitate access to stored LOs and they provide an extension to these basic functionalities of LORs by identifying additional functionalities, such as browsing and contribution. In their definition, they also refer to the role of LOs metadata descriptions in LORs. IMS (2003) also supports the distinction between the LOs and their metadata descriptions presented in LORs by arguing that LOs and their metadata could be stored in different digital repositories. McGreal (2004) proposes an additional functionality of LORs, namely, quality control mechanisms. The next three definitions provided by Lehman (2007), Ochoa & Duval (2008) and Tzikopoulos, Manouselis, and Vuorikari (2009) cover most of the issues that were presented in all other previously mentioned definitions and they also discuss the need for LORs to facilitate the efficient sharing, use and reuse of LOs.

However, it should be mentioned that all these LORs' definitions are covering a wide time frame and it is reasonable to incorporate the requirements imposed by the needs and the available web technologies of the specific time period.

Table 1
Definitions of LORs

Author(s)	Definition
Higgs, Meredith, and Hand (2003, p. 60)	"*LORs are systems that provide access to LOs through specific features, namely search/browse, retrieval, submission, storage and publishing. These systems may present LOs physically stored along with metadata in their databases or only metadata with pointers to the LOs*"
IMS (2003, p. 3)	"*A collection of educational 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*"
McGreal (2004, p. 3)	"*LORs are systems that enable users to locate, evaluate and manage learning objects through the use of "metadata", namely descriptors or tags that systematically describe many aspects of a given learning object, from its technical to its pedagogical characteristics*"
Lehman (2007, p. 61)	"*LORs are electronic databases that accommodate a collection of small units of educational information that can be accessed for retrieval and use. They enable the organization of learning objects, improve efficiencies, enhance learning object reuse and support learning opportunities. Repositories can consist of one database or several databases tied together by a common search engine*"
Ochoa & Duval (2008, p. 226)	"*LORs are digital libraries containing primarily educational material. Their main purpose is to enable the sharing of the material for its reuse in educational environments*"
Tzikopoulos, Manouselis, and Vuorikari (2009, p. 44)	"*LORs are systems which facilitate the storage, location and retrieval of LOs that are stored in their databases but also the sharing and the reusability of LOs*"

Despite this concern, based on the above discussion we can extract a common conclusion derived from all these studies. LORs are mainly considered and studied as web-based "digital repositories of LOs" since they provide typical functionalities of digital repositories to their end-users for storage, search and retrieval of LOs through the

use of metadata. The limitation of this approach is that LORs' end-users (that is teachers and students) are given limited opportunities to provide their feedback and experiences about the use of LOs that are stored in LORs, as well as end-users interactions are not facilitated. Next, we discuss these interactions as part of the different types of educational knowledge, which can be generated and shared with educational communities of practice.

3. Knowledge management in web-facilitated educational communities of practice

Communities of practice (CoP) have become increasingly influential within several fields since they are identified as an important mechanism through which individual and group knowledge is created and transferred (Cox, 2005). CoPs that are facilitated by web-technologies are referred to as web-facilitated communities of practice or virtual communities of practice (Hara, Shachaf, & Stoerger, 2009; Lin, Lin, & Huang, 2008). The concept of CoP has also become very popular in the field of education and learning. As a result, educational communities of practice are being developed focusing on generating, sharing and reusing different types of educational knowledge (McLaughlin & Talbert, 2006). The different types of educational knowledge, which can be generated and shared within educational communities of practice, can be divided into two types: (Cochran-Smith & Lytle, 1999):

- **Knowledge for educational practice:** this is formal knowledge depicted in the LOs that are constructed by teachers and/or instructional designers in an educational community and they can be used to enhance teachers' day-to-day educational practice. This type of knowledge can be considered as explicit, since it can be articulated codified and stored in certain media (Ronald & Kulkarni, 2007; Tiwana, 2003).
- **Knowledge of educational practice:** this type of knowledge is constructed: (a) by teachers based on their experiences about their students' learning and evidence of their progress in relation to given LOs, (b) by students based on their experiences about the use of given LOs provided by their teachers, and (c) by teachers-students interactions with these LOs. This type of knowledge can be considered as tacit, since it needs special effort to be codified and transferred (Tiwana, 2003).

In order to build systems that facilitate the aforementioned knowledge types in the context of web-facilitated educational communities, Charlier et al. (2007) and Goel, Junglas, and Ives (2009) have identified a set of needs for web-facilitated communities of practice that should be addressed by these systems. These needs could be adapted accordingly, so as to be applicable to web-facilitated educational communities of practice and they can be presented as requirements of such systems and in relation with the aforementioned knowledge types. These requirements are: (i) stimulating the participation of educational community members and fostering their active involvement, (ii) accommodating informal and spontaneous interactions, (iii) empowering the individuals in the process of sharing explicit knowledge for educational practice and tacit knowledge of educational practice, (iv) fostering and stabilizing community members' relationships, so as to raise the level of collaboration, communication and contribution within the community, (v) building trust between community members, (vi) simplifying access to the community with appropriate facilities (infrastructure, tools and services), (vii) distinguishing different levels of participation by identifying active contributing members of the community and acknowledge them and (viii) maintaining the sense of

being part of the community with appropriate facilities (infrastructure, tools and services) that would raise the members' sense of being part of the community.

Additionally, in order to support typical KM processes in the context of web-facilitated communities of practice, Tang, Avgeriou, Jansen, Capilla, and Ali Babar (2009) have identified eight (8) specific activities that web-facilitated community members should execute. For the purpose of our work, we have adapted these activities accordingly, so as to be applicable to web-facilitated educational communities of practice and they are presented below in relation with the aforementioned requirements.

- **Activity A – Construct Knowledge:** During this activity the members of the community (either as individuals or as members of a group) create new LOs (that is explicit knowledge for educational practice) and/or they provide their experiences in using available LOs (that is tacit knowledge of educational practice) using the available infrastructure. Both educational knowledge types can then be shared within the community (Activity C – Share Knowledge)
- **Activity B – Synthesize Knowledge:** During this activity the members of the community (either as individuals or as members of a group) use the existing educational knowledge in its explicit form (namely, LOs) and/or in its tacit form (namely, experiences in using available LOs via forum discussions, blog posts, social tagging, personal messages and/or wikis), in order to support Activity A – Construct Knowledge.
- **Activity C – Share Knowledge:** This activity is twofold. The members of the community (either as individuals or as members of a group) (i) share the explicit educational knowledge (LOs) that was constructed during Activity A and/or (ii) share their tacit educational knowledge through web 2.0 tools (namely, blogs, wikis, social tagging and social networks)
- **Activity D – Learn:** During this activity the members of the community (either as individuals or as members of a group) use the knowledge presented in the community by either searching/retrieving it (Activity H – Search/Retrieve Knowledge) or by using Web 2.0 tools (Activity B – Synthesize Knowledge), so as to enhance their learning.
- **Activity E - Evaluate Knowledge:** During this activity the members of the community (either as individuals or as members of a group), perform some type of formal or informal (through simple reflections) evaluations on the educational knowledge which is presented in the web-facilitated educational community. The members may rate and comment on the appropriateness of the LOs presented in the community by using Web 2.0 tools (Activity B – Synthesize Knowledge).
- **Activity F – Distill Knowledge:** During this activity the members of the community (either as individuals or as members of a group), assess the design of explicit educational knowledge (depicted in LOs), in order to identify patterns that may lead to the extraction of general designs for later use and/or reuse.
- **Activity G – Apply Knowledge:** During this activity the members of the community (either as individuals or as members of a group) use the educational knowledge which is available in the community by applying it in their own educational practices. This can lead to the creation of new explicit and/or tacit educational knowledge (Activity A – Construct Knowledge)

- **Activity H – Search/Retrieve Knowledge:** During this activity the members of the community (either as individuals or as members of a group) search and retrieve the existing educational knowledge that is available within the community, in order to support all the above mentioned activities

As a result, and based on the issues about the different types of educational knowledge that needs to be organized and shared within educational communities, it is reasonable to study LORs as KMSs and identify additional functionalities, which can support organization and sharing of educational communities' explicit and tacit knowledge.

4. LORs and KMSs comparative study

4.1. Research study

The main issues that we attempt to investigate in this work are:

I1: What are the core functionalities of current LORs and to what extent are they used in the selected LORs?

Through the careful review of studies on the topic of LORs, we have identified different functionalities related to three (3) different dimensions, namely Learning Objects, Metadata Descriptions and Added-Value Services. Thus, it is useful to create a "master" list of current functionalities available in existing LORs and study their level of adoption among popular and widely used LORs.

I2: What are the core functionalities of current KM systems facilitated by Web 2.0 Technologies?

Based on the issues raised in section 2, namely, the different types of educational knowledge that needs to be organized and managed within educational communities, Knowledge Management Systems facilitated by Web 2.0 Technologies are studied to devise a list of functionalities, which can be then mapped to the "master" list of existing LORs' functionalities, so as to identify missing extra functionalities of LORs.

I3: Can we devise a list of "design principles" of a LOR system through the comparison of LORs' functionalities to KM systems functionalities?

By comparing the two lists, we aim to devise an extended "master" list of LORs functionalities that could support the knowledge management processes performed among educational communities' members, as they were discussed in section 3.

Currently there are several operating LORs available at the web, which present different features, where as "features" we define the aspects of LORs that do not have direct relation with the interaction of end-users (that is teachers and students) with the LORs and they are independent of their functionalities. Based on this we used the unique features of different LORs as criteria for the selection of the LORs to be studied. For the purpose of our work the selection criteria are:

Table 2
List of selected LORs

Nr.	Examined LORs	Selection Criteria						LOR Category
		1	2	3	4	5	6	
1	Ariadne (http://www.ariadne-eu.org)	All Sectors	Cross-Disciplinary	International	Multi-lingual	LOs and Links	Free under GNU General Public Licence	Large
2	COSMOS (http://www.cosmosportal.eu)	Primary, Secondary Education and Higher Education	Science Education	International	Multi-lingual	LOs and Links	Free under CC	Large
3	eAccess2Learn (http://www.eaccess2learn.eu)	Vocational Training	Cross-Disciplinary	International	Multi-lingual	LOs and Links	Free under CC	Small
4	EdNA (http://www.edna.edu.au)	All Sectors	Cross-Disciplinary	International	English	LOs and Links	Free under CC	Large
5	FREE (http://free.ed.gov)	Primary and Secondary Education	Cross-Disciplinary	National (U.S.A.)	English	Links	Free under CC	Small
6	LRE (http://lreforschools.eun.org)	Primary and Secondary Education	Cross-Disciplinary	International	Multi-lingual	Links	Free under CC	Large
7	Jorum (http://open.jorum.ac.uk)	Further and Higher Education	Cross-Disciplinary	National (U.K.)	English	LOs and Links	Free under CC	Small
8	Merlot (http://www.merlot.org)	Higher Education	Cross-Disciplinary	International	Multi-lingual	Links	Free under CC	Large
9	MIT OCW (http://ocw.mit.edu)	Higher Education	Cross-Disciplinary	International	Multi-lingual	LOs and Links	Free under CC	Small
10	Netlib (http://www.netlib.org)	N/A	Mathematics	International	English	LOs and Links	Free under no licence mentioned	Small
11	NLN Materials (http://www.nln.ac.uk)	Further Education	Cross-Disciplinary	National (U.K.)	English	LOs and Links	Free (needs registration) under Custom Licences	Small
12	SMETE (http://www.smete.org)	All Sectors	Cross-Disciplinary	National (U.S.A.)	English	Links	Free under Custom Licences	Medium
13	OER Commons (http://www.oercommons.org/)	Primary, Secondary Education and Post-secondary education	Cross-Disciplinary	International	English	LOs and Links	Free under CC	Medium
14	Wisc Online (http://www.wisc-online.com/)	Higher Education	Cross-Disciplinary	International	English	LOs and Links	Free and Commercial under Custom Licences	Small

- **Criterion 1 - Educational Sector:** refers to the educational sector that the LOs featured in a repository target. Thus, we have selected repositories that target (a) school education, (b) further and higher education and (c) vocational training
- **Criterion 2 - Subject Domain:** refers to the subject domain that the LOs featured in a repository target. Thus, we have selected (a) thematic (that is, only one subject domain) and (b) cross-disciplinary (that is, more than one subject domains).
- **Criterion 3 - Region Coverage:** refers to regional features of the community that a LOR targets. Thus, we have selected (a) national LORs and (b) international LORs.
- **Criterion 4 - Languages:** refers to the languages supported by the LOR. Thus, we have selected (a) multilingual LORs and (b) single language LORs.
- **Criterion 5 - Type of Storage Offered:** refers to the type of storage offered by LORs. Thus, we have selected (a) LORs that store both LOs and links to external LOs along with their related metadata and (b) LORs that store only links to external LOs along with their related metadata
- **Criterion 6 - Licenses:** refers to the type of licenses associated with the LOs available in the LORs. Thus, we have selected (a) LORs with free usage of their LOs under specific licenses such as the Creative Commons (CC) license and (b) LORs with both free and commercial licenses for their LOs.

Moreover, in order to cover a broad spectrum of operating LORs, we have selected LORs from three major categories (Tzikopoulos, Manouselis, and Vuorikari, 2009): (a) those have more than fifty thousand LOs (large LORs), (b) those have from ten to fifty thousand LOs (medium LORs) and (c) those have less than ten thousand LOs (small LORs). The next step was to identify a list of currently operating LORs, so as to select appropriate LORs according to our selection criteria. A list of fifty-one LORs provided by the WikiEducator (http://wikieducator.org/) has served as our initial selection pool, which enriched with LORs that have been located throughout research in related publications and Internet sources. Finally, we selected fourteen operating LORs, which can cover all different cases of our selection criteria. Table 2 summarizes the selected LORs.

4.2. Identification and codification of LORs main functionalities

Through the critical review of previous studies about LORs, presented in section 3, we observe that there are functionalities related to three different components which constitute a LOR. Thus, in order to define the main functionalities of each LOR under investigation we consider that each LOR is built around the following components:

- **Learning Objects Component Dimension:** The functionalities related to this LOR component enable LORs' users to interact with either the LOs locally hosted by the LOR or the links to externally hosted LOs, in various ways, such as store, search, browse, view, download, rate/comment, bookmark and automatic LOs recommendations.
- **Learning Objects Metadata Descriptions Component Dimension:** The functionalities related to this LOR component enable LORs' users to interact with the metadata descriptions of the LOs, in various ways, such as store, view, download, validate and social tagging.

- **Added-Value Services Component Dimension:** The functionalities related to this LOR component aim to enhance the experience of the LORs users in relation to the other two dimensions including services such as the creation of personal accounts, forums, wikis and RSS feeds for new LOs added to the LOR.

Next, we discuss in detail the main functionalities of each LOR component dimension.

4.2.1. LORs' functionalities related to LOs

The LORs' functionalities related to the LOs component dimension can be summarized and described as follows:

1. **Store:** This functionality enables LOR's users to store in the LOR their LOs and/or links to external LOs, so as to be able to reference them with unique URLs for future use and sharing them with other users.
2. **Search:** This functionality enables users to search LOs using appropriate commonly agreed terms which are matched with metadata descriptions of the LOs. In many LORs, this functionality is often divided as simple search, when the user is using a small key set of searching criteria and advanced search, when the user is using the full set of searching criteria. In this study we refer to both simple and advanced search as "Search" functionality.
3. **Browse:** This functionality enables users to browse LOs according to different classifications based on their metadata descriptions.
4. **View:** This functionality enables users to preview the content of the LOs.
5. **Download:** This functionality enables users to download the LOs and further use them or modify them locally (when the license associated with this LO permits modifications).
6. **Rate/Comment:** This functionality enables users to provide their ratings and comments for the LOs stored in a LOR. These ratings and comments could be related with the impressions of the users who have used a specific LO within a certain context of use.
7. **Bookmark:** This functionality enables users to bookmark LOs and add them to their personal and/or favourite lists, so as to be able to access them more easily in the future.
8. **Automatic Recommendations:** This functionality analyzes users' previous actions regarding LOs search and retrieval, and it automatically recommends to them appropriate LOs that are related with the LOs that has been previously searched and retrieved.

4.2.2. LORs' functionalities related to LOs metadata descriptions

Metadata descriptions allow the creation of LOs catalogues and indexes, as well as, searching mechanisms based on these characteristics. A commonly accepted way for describing LOs with metadata is the IEEE Learning Objects Metadata (LOM) Standard (IEEE LTSC, 2005). As a result, most of the LORs developed worldwide adopt the IEEE LOM Standard or an Application Profile of IEEE LOM for describing their LOs aiming to facilitate their interoperability with other LORs (McGreal, 2008). Thus, LORs include functionalities related to the LOs Metadata Descriptions Component Dimension, which can be summarized and described as follows:

1. **Store:** This functionality enables users to store in the LOR the metadata descriptions of their LOs, so as to be able to reference them with unique URLs for future use. In most of the existing LORs, the metadata descriptions are stored in XML format and they are conformant with IEEE Learning Objects Metadata Standard or an appropriately designed application profile of IEEE LOM (Smith, Van Coillie, & Duval, 2006).
2. **View:** This functionality enables users to view in details the metadata descriptions of LOs, so as to be able to decide whether to use or not a specific LO.
3. **Download:** This functionality enables users to download the metadata descriptions of LOs in XML format conformant with IEEE LOM Standard, so as to further process them with appropriate educational metadata authoring tools and upload them back to the same LOR or to another LOR.
4. **Validate:** This functionality is used for validating the appropriateness and the quality of the metadata descriptions provided for the LOs by their authors and in many LORs this functionality is available to a limited number of back-end users (namely, metadata experts), who undertake the task to ensure the quality of metadata descriptions.
5. **Social Tagging:** This functionality enables end-users to characterize LOs by adding tags to them. LORs that support social tagging of LOs provide also the capability to their users to search and retrieve LOs based on the tags added by other users (Sampson, Zervas, & Kalamatianos, 2011a).

4.2.3. LORs' functionalities related to added-value services

The functionalities that are related to the Added-Value Services Component Dimension can be summarized and described as follows:

1. **Personal user accounts:** This functionality enables users to create and manage their own personal accounts by completing their personal information and preferences. User accounts include also information about: (a) the LOs that a user has contributed to the LOR, (b) the LOs that the user has bookmarked and (c) the ratings/comments and tags that the user has provided to the different LOs of a LOR.
2. **Forums:** This functionality enables users to communicate and exchange ideas in an asynchronous way about the use of LOs that are stored in a LOR.
3. **Wikis:** This functionality facilitates users to create wikis and share information about their experiences with the LOs that are stored in a LOR.
4. **RSS Feeds:** This functionality enables users to be informed via RSS readers about new LOs, which are added to the LOR without visiting the LOR.

4.3. LORs comparative study

Based on the above identification and codification of the LORs functionalities, Table 3 presents a comparative view of the selected LORs, so as to analyze to what extent the LORs examined in our study implement the identified functionalities.

Table 3
A comparative view of LORs functionalities

LORs Functionalities	Penetration Level	Examined LORs													
		ARIADNE	COSMOS	eAccess2Learn	EdNA	FREE	LRE	Jorum	Merlot	MIT OCW	Netlib	NLN Materials	SMETE	OER Commons	Wisc Online
LOs Component															
Store	13/14	✓	✓	✓	✓	—	✓	✓	✓	✓	✓	✓	✓	✓	✓
Search	14/14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Browse	14/14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
View	14/14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Download	10/14	✓	✓	✓	✓	—	—	✓	—	✓	✓	✓	✓	✓	—
Rate/Comment	7/14	—	✓	✓	—	—	✓	✓	✓	—	—	—	✓	✓	—
Bookmark	6/14	—	✓	—	✓	—	✓	—	✓	—	—	—	—	✓	✓
Automatic Recommendations	2/14	—	—	—	—	—	—	—	✓	—	—	—	—	—	✓
LOs Metadata Descriptions Component															
Store	14/14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
View	14/14	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Download	2/14	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—
Validate	5/14	✓	✓	✓	—	—	✓	—	✓	—	—	—	—	—	—
Social Tagging	2/14	—	—	—	—	—	✓	—	—	—	—	—	—	✓	—
Other Added-Value Services															
Personal Accounts	11/14	✓	✓	✓	✓	—	✓	✓	✓	—	—	✓	✓	✓	✓
Forums	8/14	—	✓	✓	✓	—	—	✓	✓	—	—	—	✓	✓	✓
Wikis	1/14	—	—	—	—	—	—	—	—	—	—	—	—	✓	—
RSS Feeds	1/14	—	—	—	—	—	—	—	—	—	—	—	—	✓	—

As we can notice from Table 3 LORs' functionalities related to LOs such as "Store", "Search", "Browse", "View" and "Download" are implemented by the most LORs examined in our study and they can be considered as core LORs' functionalities related to LOs component dimension. On the other hand, LORs' functionalities related to LOs such as "Rate/Comment", "Bookmark" and "Automatic Recommendations" are implemented by a limited number of the examined LORs. Concerning the functionalities related to LOs Metadata Descriptions, "Store" and "View" are implemented by the most

LORs examined in our study and they can be considered as core LORs' functionalities related to LOs Metadata Descriptions component dimension. However, functionalities such as "Download", "Validate" and "Social Tagging" are less implemented by the examined LORs. Finally, functionalities related to Added-Value Services such as "Personal Accounts" and "Forums" are implemented by the most LORs examined in our study and they can be considered as core LORs' functionalities related to Added-Value Services component dimension, whereas functionalities such as "Wikis" and "RSS Feeds" are implemented only by one from the examined LORs, so these functionalities are not popular in current LORs implementations.

4.4. Identification and codification of KMSs functionalities

Knowledge is considered valuable and useful, mainly when it can be organized, shared and re-used. For this purpose, information systems are established in organizations to facilitate the collection, integration and dissemination of knowledge within these organizations. These systems refer to Knowledge Management Systems (KMSs) (Alavi & Leidner, 2001). KMSs support the integrated knowledge management process for maximizing the value of the knowledge assets within organizations, where knowledge assets are defined as: "*any collected information or knowledge held by an organization and used by anyone affiliated with the organization to help the organization achieve its goals*" (Ronald & Kulkarni, 2007, p. 103). Knowledge assets can be divided into (Ma & Heemje, 2002):

- **Explicit knowledge assets**, which can be articulated, codified and stored in certain media (such as documents, specifications, manuals, etc). Explicit knowledge assets are stored in knowledge repositories along with their related metadata, which are data that help to define and understand the characteristics, traits and use of explicit knowledge asset items (Anand & Sing, 2011).
- **Tacit knowledge assets**, which mainly reside in people's brains and are difficult to be transferred to another person by means of writing them down or verbalizing them (such as know-how, procedures, processes, etc). Tacit knowledge assets are converted to explicit knowledge assets and shared among individuals through the process of evaluation, discussion and collaboration (Anand & Sing, 2011).

With the emergence of Web 2.0 technologies, approaches to knowledge management are shifting from the traditional knowledge management approach focusing on collecting knowledge in a centralized repository and its accessibility to a Web 2.0 approach emphasizing on the integration and collaboration of knowledge creation within communities of practice (Du & Wanger, 2011). As a result, knowledge from specific disciplines is no longer provided and assessed solely by the domain experts, but also by the peers by using Web 2.0 tools.

Based on the above discussion and from relevant studies in the literature, we can identify the key functionalities of KMSs supported by Web 2.0 technologies. These functionalities can be divided in two categories (Islam, Kunifuji, Miura, & Hayama, 2011; Antonova, Gourova, & Roumen, 2009): (a) those that are related with explicit knowledge assets management and (b) those that are related with tacit knowledge assets management in terms of providing the collaborative working environment and services to the end-users, so as to work together for converting tacit knowledge assets to explicit knowledge assets. Next, we present these functionalities according to the aforementioned categories, as extracted from studying the relevant works available in literature (Antonova, Gourova,

& Roumen, 2009; Benbya, 2008; Bibikas et al., 2008; Holsapple, 2003; Ma & Heemje, 2002; Perez-Araos, Barber, Eduardo Munive-Hernandez, & Eldridge, 2007; Scherp, Schwagereit, & Ireson, 2009; Schneckenberg, 2009):

- **Category 1: Explicit Knowledge Assets Management**
  - **Deposit:** Enables KMS's users to deposit in a centralized knowledge repository explicit knowledge, so as to be able to reference them with unique URLs for future use and sharing them with other users
  - **Search:** Enables KMS's users to search explicit knowledge assets using terms, which are matched with explicit knowledge assets metadata.
  - **Browse:** Enables KMS's users to browse explicit knowledge assets based on different classifications
  - **View:** Enables KMS's users to preview the content of explicit knowledge assets
  - **Download:** Enables KMS's users to download explicit knowledge assets and further use them or modify them locally.
  - **Rate/Comment:** Enables KMS's users to provide ratings and comments regarding the explicit knowledge assets that are stored in the KMS. These ratings and comments could be related with the impressions of the end-users who have used a specific knowledge asset within a certain business process.
  - **Knowledge Filter:** This functionality is used in order to provide KMS's users with better rankings of explicit knowledge assets during their searching, which are based on other users' comments and ratings.
  - **Automatic Recommendations:** This functionality focuses on the suggestion of explicit knowledge assets that are relevant to previous users' search queries.
  - **Bookmark:** This functionality enables end-users to bookmark explicit knowledge assets and add them to their personal and/or favorite lists, so as to be able to access them more easily in the future.
  - **Mash-ups:** Mash-ups refer to web applications which present data acquired from different sources and combined in a way which delivers new functions or insights. This functionality enables KMS's users to search and retrieve explicit knowledge assets from other systems and applications.
  - **Annotate:** This functionality enables the creators of explicit knowledge assets to annotate them by adding tags to them, so as to be searchable and retrievable from other KMS's end-users.
  - **View Annotations:** This functionality enables KMS's end-users to view the tags of explicit knowledge assets that has been added by the creator of the specific knowledge asserts, so as to be able to decide whether to use it or not.
  - **Social Tagging:** This functionality enables KMS's end-users to collaboratively annotate explicit knowledge assets by adding tags to them and providing also to other users to search and retrieve explicit

knowledge assets based on the tags added not only by the creators of the explicit knowledge assets but also from their peers.

- **Category 2: Tacit Knowledge Assets Management**
  - **Personal User Accounts:** This functionality enables users to create and manage their own personal accounts by completing their personal information and preferences. User accounts include information about: (a) the explicit knowledge assets that a user has contracted and deposited to the KMS, (b) the explicit knowledge assets that the user has bookmarked and (c) the ratings/comments and tags that the user has provided to its own explicit knowledge assets or to explicit knowledge assets deposited to the KMS by his/her peers.
  - **Forums:** This functionality enables KMS's end-users to communicate and exchange ideas in an asynchronous way about the explicit knowledge assets stored in the KMS.
  - **RSS Feeds:** This functionality enables KMS's end-users to be informed via RSS readers about new explicit knowledge assets added to the KMS or about updates performed to existing explicit knowledge assets.
  - **Wikis:** This functionality enables KMS's end-users to work collaboratively and create, edit, and share explicit knowledge assets.
  - **Blogs:** This functionality enables KMS's users to build and maintain their own blogs for publishing their opinions about explicit knowledge assets stored in KMS and receiving comments from other end-users about their reflections.
  - **Social Networks:** This functionality enables KMS's end-users to build online social networks based on the explicit knowledge assets that they are offering to the KMS, so as to share their common interests.

4.5. Mapping LORs functionalities to KMSs functionalities

In this section, we provide a mapping between LORs and KMSs functionalities, so as to identify additional LORs functionalities that can support organizing and sharing of the different types of educational communities' knowledge, as discussed in section 2. Table 4 depicts the mapping.

As we can notice from Table 4 there are four functionalities, namely "knowledge filters", "blogs", "social networks" and "mash-ups" that cannot be mapped to any of the existing LORs' functionalities. The "knowledge filter" and "Mash-ups" functionalities can be used in existing LORs implementations for enhancing the sharing of educational communities' explicit knowledge (depicted in LOs). In particular, the "knowledge filter" functionality can provide to LORs' end-users better LOs rankings during their searching, which could be based on other users' comments and ratings about the LOs or they could be based on the content of the LOs themselves. Additionally, the "mash-up" functionality could provide to LORs' end-users the capability to extend their access beyond locally available LOs to a variety LOs collected in other LORs. This means that LORs' end-users can access a large number of LOs that may cover a variety of scientific domains, age ranges and languages. The other two functionalities (namely, "blogs" and "social networks") can be used in existing LORs implementations for enhancing sharing of educational communities' tacit knowledge (depicted in teachers' and students'

experiences and interactions in using available LOs) and converting it to explicit knowledge. More specifically, the "blog" functionality can provide to LORs end-users the capability to build their own blogs for publishing their opinions about their LOs stored in LORs and receive feedback from other users. Finally, the "social networks" functionality can support LORs end-users in connecting with other users and following their activities such as the new LOs uploaded to the LOR or new comments/ratings added to LOs.

On the other hand, we should mention that there are also two functionalities identified in LORs (namely "download metadata" and "validate metadata"), which are not mapped to any KMSs's functionalities. This is due to the fact that LORs are using formal metadata models (such as IEEE LOM Standard) to characterize their LOs, whereas KMSs supported by Web 2.0 technologies follow annotating approaches for their explicit knowledge assets that do not use formal metadata models and consequently these functionalities are not essential in the context of KMSs supported by Web 2.0 technologies.

Table 4
Mapping of LORs and KMSs functionalities

Nr	Identified LORs Functionalities	Identified KMSs Functionalities
	LOs Component	***Explicit Knowledge Assets Category***
1	Store	Deposit
2	Search	Search
3	Browse	Browse
4	View	View
5	Download	Download
6	Rate/Comment	Rate/Comment
7	Bookmark	Bookmark
8	Automatic Recommendations	Automatic Recommendations
9	**N/A**	**Knowledge Filter**
10	**N/A**	**Mash-ups**
	Metadata Component	
11	Store	Annotate
12	View	View
13	Download	N/A
14	Validate	N/A
15	Social Tagging	Social Tagging
	Other Added-Value Services	***Tacit Knowledge Assets Category***
16	Personal Accounts	Personal Accounts
17	Forums	Forums
18	Wikis	Wikis
19	RSS Feeds	RSS Feeds
20	**N/A**	**Blogs**
21	**N/A**	**Social Networks**

5. Findings and discussion

Based on Table 4, it appears that existing functionalities of commonly used LORs do not meet the requirements of current KMSs supported by Web 2.0 technologies. As a result, in this paper we aim to propose an extended list of LORs' functionalities that meet the current demands of web-facilitated educational communities and the KM activities that they execute, as identified in section 2. To this end, for each KM activity identified in section 2, we identify those functionalities that are needed to meet each of these activities. Table 5 presents the mapping between the KM Activities that web-facilitated educational communities of practice execute and the proposed extended list of LORs' functionalities that support each of these activities.

Table 5
KM activities of Web-facilitated educational communities mapped to extended LORs functionalities

	Extended List of LORs Functionalities																										
KM Activities	**LOs Component**	Store	Search	Browse	View	Download	Rate/Comment	Bookmark	Automatic Recommendations	Knowledge Filter	Mash-ups	**LOs Metadata Component**	Store	View	Download	Validate	Social Tagging	**Other Added-Value Services**	Personal Accounts	Forums	Wikis	RSS Feeds	Blogs	Social Networks
A		✓	—	—	—	—	✓	—	—	—	—		✓	—	—	✓	✓		—	—	—	—	—	—
B			—	—	—	—	—	—	—	—	✓		—	—	—		✓		—	✓	✓	—	✓	✓
C		✓	—	—	—	—	—	—	—	—	—		✓	—	—	—	✓		—	✓	✓	—	✓	✓
D		—	—	—	✓	✓	—	—	—	—	—		—	✓	✓	—	—		—	✓	✓	—	✓	✓
E		—	—	—	—	—	✓	—	—	—	—		—	—	—	✓	✓		✓	✓	✓	—	✓	✓
F		—	—	—	✓	✓	—	—	—	—	—		—	—	—	—	—		—	—	—	—	—	—
G		—	—	—	✓	✓	—	—	—	—	—		—	✓	✓	—	—		—	✓	✓	—	✓	✓
H		—	✓	✓	✓	—		✓	✓	✓	✓		—	—	—	—	—		—	—	—	—	—	—

As we can notice from Table 5, it appears that all KM Activities executed by the members the web-facilitated educational communities of practice can be addressed by the proposed extended list of LORs' functionalities. As a result, building LORs that follows the proposed functionalities can support the management of the web-facilitated educational communities' explicit and tacit knowledge.

6. Conclusions and future work

In this study, through the systematic examination of a broad spectrum of existing LORs, we claim that LORs' functionalities need to be revisited from a KM perspective, so as to be able to support activities related with typical KM processes in the context of web-facilitated educational communities of practice. The results of our study can drive future development and deployment of enhanced knowledge intensive LORs that will include the proposed functionalities towards supporting the management of different types of educational knowledge within web-facilitated educational communities of practice. This

means that these enhanced LORs will be able to facilitate not only the management of LOs as digital assets (carrying explicit knowledge) but also the organization and management of the end-users (namely, teachers and students) experiences and interactions with these LOs (which can be recognized as tacit knowledge).

However, it should be mentioned that explicit knowledge management within web-facilitated educational communities cannot be fully depicted to LOs without considering also Learning Designs (LDs) (Koper & Olivier, 2004) as the means to represent information about the pedagogy, as well as, the learning and educational context of LOs use. For this purpose, it would be reasonable to consider and study the design and development of web-based repositories of learning designs, which will enable their end-users (that is teachers and students) to share not only educational resources (in the form of LOs), but also learning designs that represent different pedagogical practices. An initial work towards this direction was reported in (Sampson, Zervas, & Sotiriou, 2011b) and it could be significantly enhanced by incorporating the results of this study.

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