Prototype framework for integration of digital repository systems with e-learning platforms

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Abstract: Modern repository platforms like Dspace, ePrints or FEDORA (Flexible and Extensible Digital Object and Repository Architecture) are information systems and frameworks for handling digital objects. They are rich with various features so they might serve as much better interactive storage than internal LMS (Learning Management System) storage used by LSM like Blackboard or Moodle. This paper analyzes features of commonly used repository platforms as possible storage solution for e-learning digital objects and tools. We explain our experiences while creating integrated framework system for commonly used LMS with commonly used repository platforms. Comparison analysis of existing repository platforms is made with focus on features necessary for effective integration with LMS and similar e-learning systems. Prototype application was created to demonstrated key features and benefits of integrated solution.

Key-Words: - repository platforms, learning management systems, API, integration, e-learning tools, prototype application

1 Introduction

LMS have various tools based on advanced Web technologies, but often poor repositories for learning objects (LO). Basic problem is how to enable simple access to materials stored in various repositories with options to create, edit, share, collaborate and integrate them in their own courses or on any LMS.

On other hand, repository platforms are enabling users content management for academic purposes (storage and exchange of scientific content types) but they also have potential to serve for e-learning purposes. Repository platforms (RP) are advanced information systems for handling digital objects (DO) and as such they could significantly extend functionalities of LMS.

2 Why LMS-RP integration

LMS-RP integration might enable collaboration not only on institutional level. RP are usually part of some federated network so they have tools for access control, metadata or whole record exchange.

If LMS and RP are integrated than each course content could actually be collection of DO stored in RP. Sharing of those DO across federated network of DO could be enabled or disabled by institutions policy so this might enable various joint e-learning activities among educational institutions.

Current LMS platforms with options for building plugins or building blocks for extended functionalities could be significantly extended with options allowed by RP.

This could allow creation of number of additional applications which could enable editing, sharing, reusing and other options upon DO with ability to publish them afterwards on chosen courses or as joint scientific contribution in any RP.

DO in RP are usually stored with all rich metadata about structure and resources of the DO. Usually this is tiresome part for the person that submits publication of any sort. All metadata fields are usually filled manually.

LMS usually doesn't store data with metadata options and usually they have quite week capabilities regarding metadata options in general. RP on other hand are all about metadata and additional options and functionalities that could enrich user experience with DO. Convenient circumstance is that LMS holds already majority of information which needs to be stored as metadata:

- User information about teachers and students – fetch from authorization system (like

LDAP) or SIS (Student Information Systems) of the institution.

- Course and department data – information about those options is already stored in structure of the LMS while courses are created, structured in categories and described.

Having such a rich sources of information any DO generated in LMS-RP environment can be described with all that information that can be pulled either from LMS or other systems like SIS. Which means that users in LMS-RP systems are actually LMS users with ability to access federated networks of RP content with LMS credentials. That way their contributions could be tracked across network and their access could be uniquely identified.

3 LMS integration capabilities

LMS integration with other systems like SIS has been common way of communicating user data and access control on LMS courses. It is usually fairly limited type of integration because it is used to access basic information in SIS (students, professors, TAs, departments, courses,) in order to replicate same user database state inside LMS. But what about content?

Blackboard and Moodle LMS are following IMS Global standard for LTI (Learning Tools Interoperability) [1] in order to integrate content from providers like McGraw and Pearson or to allow access to full courses or activities from remote systems (other LMS installations or any other LMS LTI consumer compliant software). LTI is standard way of integrating rich learning applications (often remotely hosted and provided through third-party services) with platforms like LMS, learning portals, or other educational environments [2]. This is also powerful way to integrate LMS with cloud services in order to achieve collaborative and interactive features that often lack inside LMS environment. Integration with Google Docs is good example of that too [3].

API on both LMS are offering access to content and tools inside LMS environment and they are frequently used to create plugins (in Moodle) or building blocks (in Blackboard) environment which are extending standard functionalities.

These are usually ways LMS can be accessed but this does not mean they are offering ideal modern e-learning environment. We must keep on mind that e-learning is continuously evolving and must be ready to integrate new paradigms and consider the student as the center of the process. This shift will mean changing the tools currently used, giving way to other tools that take into account various ways of easy integrations of new services and resources with divers customization capabilities [4].

Variety of new kinds of tools and services exist today. Many educators are adopting new approach from the LMS course space towards Personal Learning Environments (PLE). But PLE is characterized by its absence of structure. This is provided by open standards and mashup techniques which are becoming increasingly important because they allow effective integration of content or service in modern web environment [5].

Main final goal is to define framework for integration which could allow easy access to RP of any kind from LMS environment for the purpose of searching, creating, editing, sharing and integrating DO in different types of LMS and similar e-learning systems. Another goal is to have friendly user interface which will enable usage of not only LO but also assest, which are smaller content units from which LO is consisted of.

Key questions is: are current platforms in (theoretical propositions or practical solutions) useful, or capable, for realizing integration between e-learning solutions and RP?

4 Current research

Current body of research, partly already cited in previous chapter, is focused on effectively achieving this integration with realization of PLE without feeling of confinement by LMS and its limiting structure. This is explained in [5] where attempt is made to create service-oriented virtual learning environment.

Evolvement of LMS with Mash-Up PLE is explained in [4]. Integration of course items from LMS (Moodle) into RP (Dspace) is attempted in [6] where authors explain about design of a competences based teaching model supported in the integration of repositories and LMS platforms.

Authors in [7] went step further and proposed integration not only with LMS but also with different libraries and students assessment systems.

Also what is obvious from current research on this topic that there is ever growing need to integrate Learning Object Repositories (LOR) with Federated metadata search engines over the Cloud infrastructure [8]. Learning objects (LO) are nothing but properly described DO with educational metadata defined by SCORM (Sharable Content Object Reference Model) [9] and RP systems are frequently used as LOR. Research shows that majority of high quality LO are actually stored in institutional LMS [10].

5 Learning Object Repositories

Object-oriented thinking has spawned the creation of small, reusable educational chunks of digital information that educators and trainers can archive or use while building courses. Those chunks are LO and they are usually stored in RP which in this case has function of LOR since its storing LO [11].

5.1 LO benefits

Usually LOR use "compound digital object" design which aggregates one or more content items (assets) into LO. Content items can be of any format and can either be stored locally, or externally with URI reference of the LO [13]. This is case with advanced RP used for LOR like FEDORA [12]. This means that content inside LMS could be referenced from any local or external LOR which is usually not possible with LMS repositories.

LO contains description metadata about itself but also about every asset in LO. This is LO metadata and it also enables discovery of LO. This is useful for sharing of metadata across networks of repositories and searching through federated networks of LOR. LO can also store different types of metadata for same object so same LO can be part of different federated networks which can perhaps relay on different metadata.

LO metadata doesn't have to be only descriptional, it can also contain explanation about structure of the LO which is necessary in case LO contains larger number of items. Structuring DO can also help in accessing items inside LO programmatically which is enabled through different API.

LO can also contain one or many service definitions for different operations with LO. In object-oriented programming terms service definitions defines an "interface" which lists the operations that are supported but does not define exactly how each operation is performed [13] so programmer can have free will on how to implement service.

This enables proper storage or creation of more complex e-learning or scholarly LO [14]. If integrated with LMS it is clear how this options could enrich current procedures for building plugins and building blocks in LMS but also enhance LMS itself.

5.2 LOR integration requirements

In case LOR should effectively serve as support for LMS following main options should be enabled:

- Search (data, assets and metadata)
- CRUD (Create, Retrieve, Update, Delete) over LO and assets
- Reusing and versioning of LO,
- Publishing options
- Creating compound LO
- Exchange of LO among other repositories (metadata or full LO),
- Ability to expose LO to internal and external services for presentation and transformation (dissemination) of LO,
- Ability to create custom data models for handling LO structure, data, resource maps and metadata.

5.3 Analysis of repository projects and software solutions

Repository projects listed here might effectively supplement LMS lack of DO management capabilities. Table 1. shows main projects in field of LOR and main LOR networks. Projects are analyzed by ability to adapt to integration features listed in previous chapter. Legend: N- not supported, Y – supported, empty – data not available.

Table 1. Repository solutions features

	PROJECTS	Metadata search	Create (API)	Edit (API)	Delete (API)	Rich API	Collaborate	Versioning	Reuse	Compound objects	Metadata	Metadata harvesting	Exchange of full DO	Publish	Permissions
	Alfresco	L	Y	Y	Y	L	Y	Y	N	Y	Y	L	L	Y	Y
	CONTENTdm	L	N	N	N	N	N	N	N	Y	L	Y	L	Y	L
	Connexions and Rhaptos	Y	Y	Y	Y	Y	Y	Y	Y		L	Y		L	
	Digital Commons	Y	N	N	N	N	L	N	N	N	L	L	N	Y	L
	DigiTool	Y	Y	Y	Y	L	L	N	N	L	Y	Y	N	L	Y
	Dspace	L	Y	Y	Y	Y	N	N	L	L	Y	Y	Y	Y	Y
	ePrints	Y	Y	Y	Y	Y	L	L	L	L	Y	Y	Y	Y	Y
	EQUELLA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	FEDORA	L	Y	Y	Y	Y	L	Y	L	L	L	Y	Y	Y	L
	intraLibrary	Y	N	N	N	N	L	N	N	N	Y	Y	N	Y	Y
	Islandora (Fedora+Drupal)	Y	Y	Y	Y	Y	L	L	Y	Y	Y	Y	L	Y	Y
	Invenio	Y	L	L	L	L	N	Y	N	N	L	Y	N	L	L
	MyCore	Y	Y	L	L	L	N	N	N	N	L	Y	N	Y	Y
	Open Repository	Y	Y	Y	Y	N	N	N	N	L	L	Y	L	L	Y
	SobekCM/Greenstone	Y	Y	Y	Y	Y	Y	Y	L	L	Y	Y	N	Y	Y
	Zentity														
federated networks	EdNA (Dspace)														
federated networks	GLOBE														
federated networks	Learning Registry	Y	Y	Y	Y	Y		L	Y	L	Y	Y	Y	Y	
federated networks	MERLOT	L	L		L										
federated networks	MIT OCW							Y				Y	Y		Y
federated networks	NC LOR	Y	Y	Y	Y				Y		L			Y	
federated networks	Open Educational Resources	Y	L		L										

Connexions is example of project which enables view and share of educational material made of small chunks of knowledge called modules that can be organized as courses, books, reports, etc. Anyone may view or contribute: authors create and collaborate, instructors rapidly build and share custom collections, and learners can find and explore content [15].

Ariadne Foundation created GLOBE (Global Learning Objects Brokering Exchange). GLOBE is a “one-stop-shop for learning resource broker organizations, each of them managing and/or federating one or more learning object repositories. GLOBE makes a suite of online services and tools available to its members for the exchange of learning resources, and is set up as a worldwide Open Community”[16]. Ariadne LOR is full of rich functionalities like enable discovery and adding of new repositories, federated search, semi-automatically generation of metadata (SAMGL project) of LO, decomposition of complex objects to basic LO but also composition of complex objects from smaller ones.

When we talk about repositories we need to mention one of the most important institutions here OAI (Open Archives Initiative). Most used open source bibliography repository software systems like Dspace, ePrints and FEDORA are fully supporting all recommendation from OAI in their implementations [17]. In 2009. institutions that are leading development of FEDORA and Dspace created joint organization called DuraSpace. DuraSpace is promoting innovations in field of storage and reuse of DO with emphasis on solutions based on open source and cloud technologies.

Different other repository solutions and supporting protocols are listed in 0. and assessed according to their own current documentation.

5.4 Repository projects analysis conclusion

Many repositories supports different functionalities but in limited way. For example Learning registry is supporting compound objects but only in form of fetching “slices” of compound object, so GET function is the only function supported upon “slices” of compound object [18]. Very word “slices” signifies step out from usually naming supported by OAI-ORE (OAI Object Reuse and Exchange) protocol which aggregates, resources and resources maps which is not same as defined in SCORM for example. So in similar way other repositories have provided their own limited functionalities upon compound objects with their own semantics.

Some repositories do not support OAI-ORE but it can be supported through plugins, Alfresco is example of such repositories.

6 Integration proposal

Tested repository projects could serve for LMS-LOR integration purposes. 0. shows schema for proposed integration.

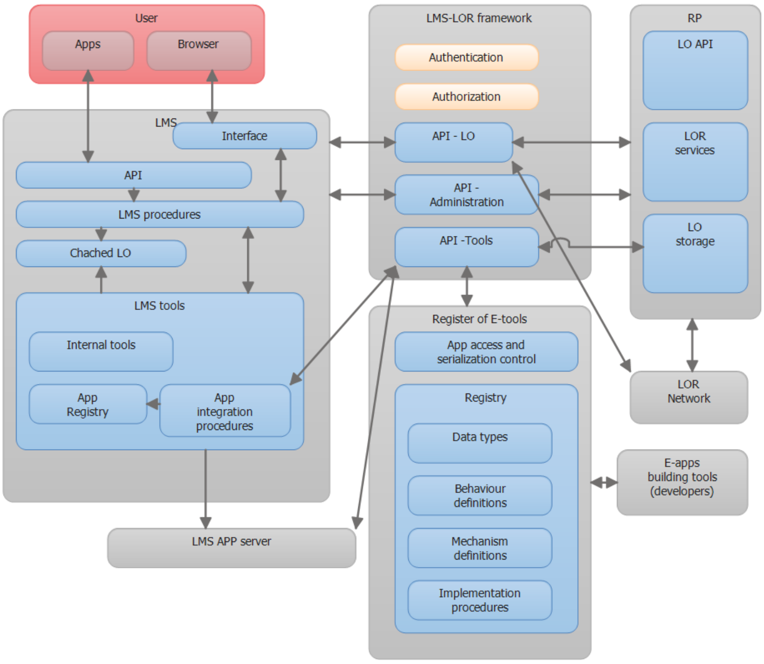

Figure 1. LMS-LOR integration schema

Interaction is based on three key parts of the system: LMS, LOR and Registry of E-learning tools which can serve as application repository for various tools for e-learning. LMS holds information about users and courses and it’s used for serving cached LO and tools from repositories on courses. Each user (student/professor) contribution is saved in LOR so LMS is not used as primary storage for LO delivery. LMS only refers to LOR where all objects are stored.

API – LO enables editing environment for creating LO which can be embedded in LMS.

From Registry of E-tools developers can extract information from LOR about various LO and build applications and tools. Applications could then be published in Registry of E-learning tools for global usage.

7 Prototype of LMS-LOR integration

Prototype application framework is created to demonstrate weather proposed framework is feasible. This application is result of two years of development and researching in this field. It was created as C# WPF application with addition of PHP and Java programming in order to build upon current features of RP and LMS. That was needed to overcome problems with current API-s and limited integration capabilities of various RP and LMS.

7.1 Metadata extraction and mapping

Our prototype application allows user storing of different documents to and from any OAI (Open Archive Initiative) supported repository like one in 0. Difference between for example GoogleDocs or SharePoint repositories and OAI based repositories is that OAI repositories relay on proper metadata to store DO in order to support additional important functionalities – exchange of metadata or whole DO with other repositories, and also sharing, publishing, archiving, federated search and integration with other system through different API. Also these repositories are open source and widely used as bibliography records and DO repository which makes them ideal choice for integration with e-learning tools.

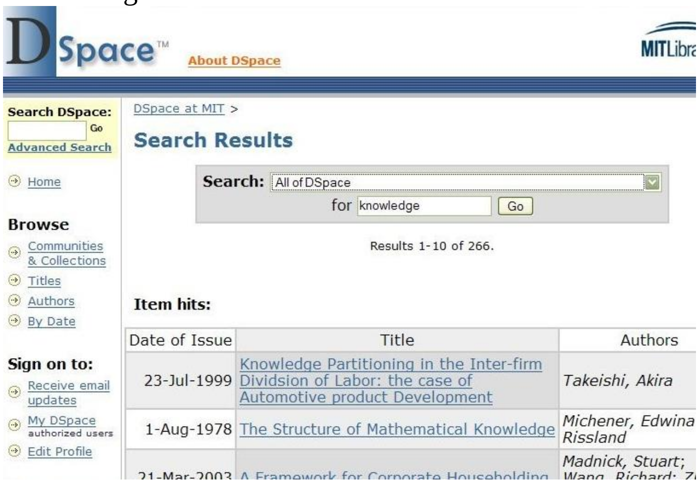

Figure 2. Example of OAI repository

Accordingly, we have created automatic recognition of MS Word, Power Point or Excel files metadata when uploading in application. User has option to change that metadata and then store it in any of supported OAI repository. Metadata is stored in standard Dublin Core record but user have options to store it also in LOM (Learning Object Metadata) or any other format.

Before depositing DO to repository user has ability to change extracted metadata from document (0.). Extraction of existing metadata in document is supported for all mentioned Microsoft types of documents.

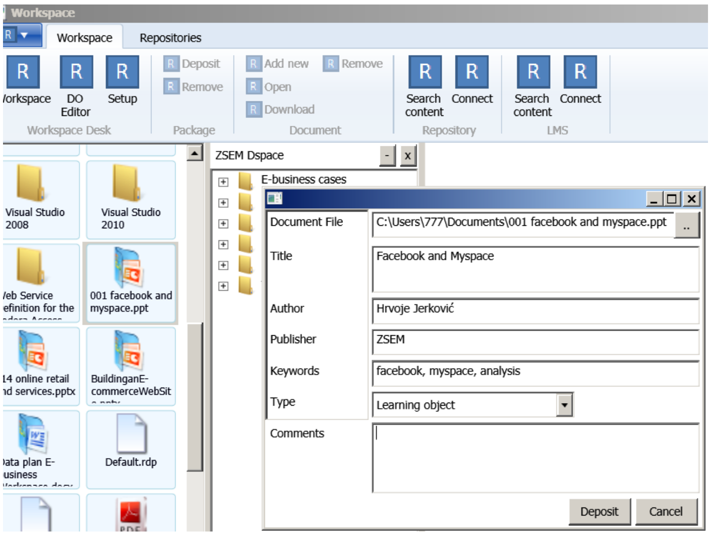

Figure 3. Form with extracted metadata from document before deposition of LO in LOR

7.2 Searching and CRUD over repositories

Our prototype application supports adding all main OAI repositories in configuration – Dspace, FEDORA and Eprints. User can be connected on one or more repositories with ability create federated search based on any DC metadata (Dublin Core metadata schema).

Adding of freely searchable OAI repositories is also available, user only has to have account opened with repository and active subscription on chosen categories. Example shows how users can define list of repositories or even only categories from repositories which can be added to application. 0. demonstrates not only searching across custom set of categories in chosen list of repositories across metadata fields but also availability to download available disseminations of stored documents in case user has proper permissions.

OAI-PMH protocol (OAI- Protocol for Metadata Harvesting) was basis of implementation and we used it to extract necessary metadata, but it can be used also be used to facilitate exchange and synchronization of metadata harvested between repositories.

OAI-ORE protocol, which allows many other disseminations of DO through ReM (Resource Maps) of objects was used for extraction of full object and its assets with all corresponding information about structure, metadata and relations of assets in DO.

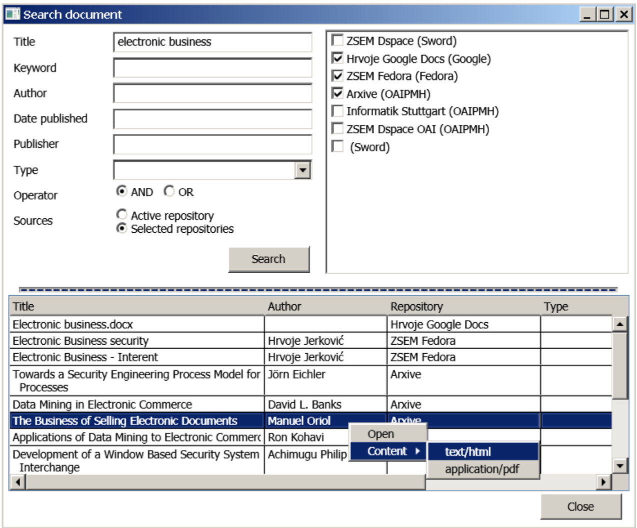

Figure 4. Searching repositories

With CRUD (Create, Retrieve, Update, Delete) permissions over given repository or individual collection inside repository user can add or delete collections, categories or DO in repository directly from application. 0. shows connection on three different repositories: Dspace (OAI type of repository), Google Docs and FEDORA (OAI type of repository). We achieved support for Google Docs but metadata support is not present since it's not supported.

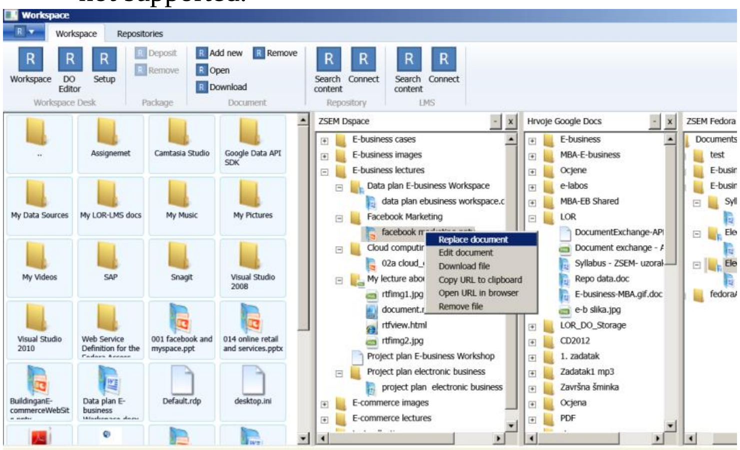

Figure 5. CRUD features over repository

7.3 DO editor

DO editor is prototype of HTML editing applications that could be connected on proposed framework application. It demonstrates ability to edit and create DO (in our case rich text format (RTF) and HTML files) from different local user materials, from other repositories or from the web and storing of such objects in any chosen repository as new DO. 0. Shows DO in the background with opened option for storing DO in any of the repositories on which user is currently connected.

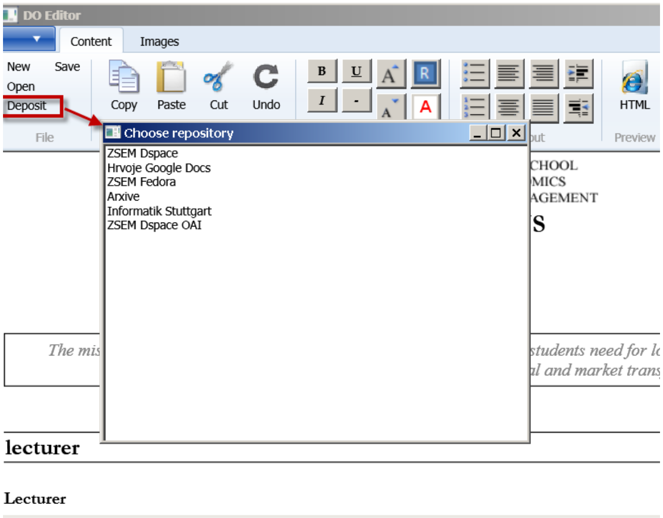

Figure 6. DO editor prototype

From DO editor user can also search other publicly available services, fetch results as objects of that search and insert them into DO editor. Classical example of Google Images and Flickr services are shown in 0. Other available services could be added in similar way.

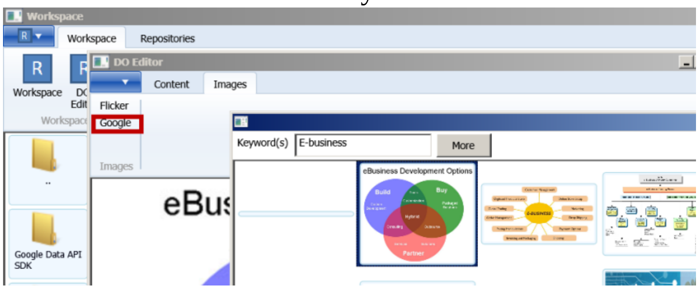

Figure 7. Integration other web services (Google and Flickr search)

Key idea is to create editing environment which user (professor or student) usually uses while creating new DO (weather that is lesson, article, book chapter, seminar, professional paper, project or anything else). And in that environment user will need: results from web searches by using classical web search services or scientific article search, results from scientific databases of articles (fetch from LOR repositories), and existing objects from courses (fetch from LMS).

DO which is created that way could be easily integrated in any LMS. We created additional functionality for FEDORA repository which enables preservation of relative links while storing DO in FEDORA repository which enables showing of whole HTML document and not only file. That way more complex DO could be created in form of mini web sites that could be embedded in LMS (0).

Individual parts of the DO can be fetch and edited (DO assets) and new version of DO could be integrated into one or several LMS courses with preservation of previous versions.

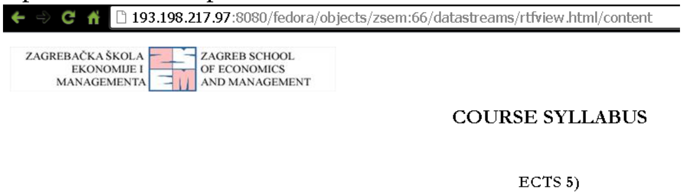

Figure 8. DO in FEDORA

8 Managing LMS activities

We have achieved integration of our demo application with two frequently used LMS (Blackboard and Moodle) and demonstrated how regular user (professor) can use our application to preform actions (grading) in Blackboard or Moodle over LO (assignments) stored in those LMS. In our case LO could also be any output/input in LMS (students' submission or professors' grade). Latter we'll explain benefits of such approach.

8. 1 Editing Blackboard objects and tools

Professor can use his own instructor Blackboard account to connect to his courses on Blackboard through our application. He can that fetch DO from different courses as well as from different tools (announcements, assignments and tests for example). User can view grades from Blackboard Grade Center and transfer them to DO editor and store them in any of his repositories on which he is currently connected (0.).

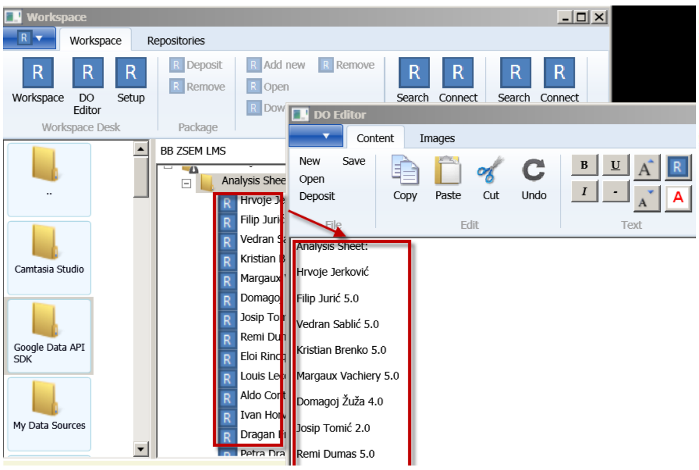

Figure 9. Grading in Blackboard

8.2 Editing Moodle objects and tools

Same options are achieved for Moodle as for Blackboard but we have added several new functionalities since Moodle is open source LMS so we were able to modify existing scripts and add several of our own to achieve new functionalities.

User can use his Moodle account to connect to his Moodle courses and tools through our application (in same way as on Blackboard).

We have implemented control for Assignment tool for grading assignments in Moodle and also view of Grade center with ability to perform fast grading with commenting on individual assignments. In our prototype application user can fetch all assignments from Moodle for all students and store them on his desktop with single drag-drop action in form of one DO with all metadata from Moodle. Or they can be graded directly without storing on users' computer.

Example in 0. shows fetching of students Word assignments which users submitted over assignments tool in Moodle and also individual student metadata data extracted from Moodle while storing assignment (Figure 10.).

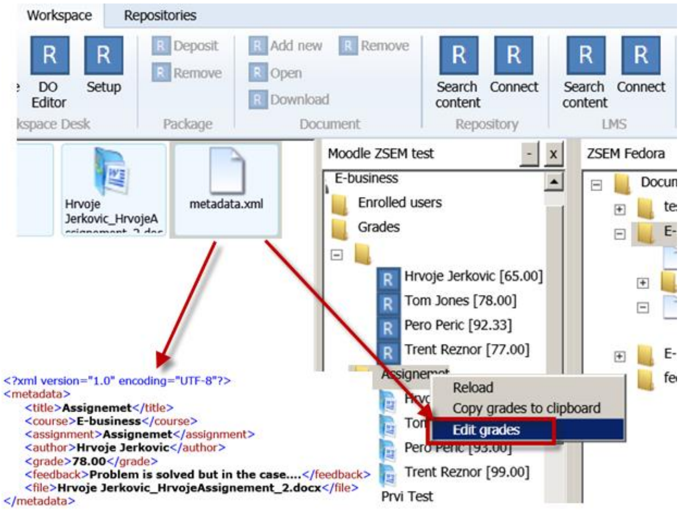

Figure 10. Editing Moodle assignment

After reviewing professor can grade all assignments directly from application (0.)

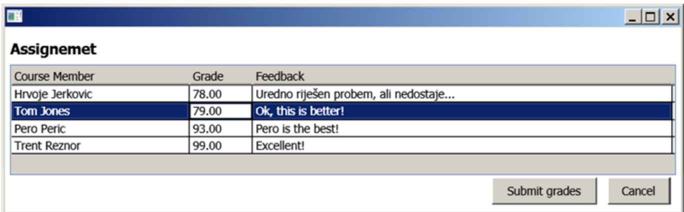

Figure 11. Grading Moodle assignment

After grading professor can deposit students' assignments in any of his LOR. LO is stored with all relevant metadata from Moodle.

8.4 Grading workflow

First we created automated extraction of relevant metadata from Moodle and assign it to all individual DO produced with single tool (in this case Assignments tool). After that we enabled transfer of DO with all metadata to user computer or any given repository on which user is connected. So this way it is possible to create automated description and storage of all students' contributions from any LMS tool (discussions, group projects, test, assignments, essays etc.) into any repository.

Professor can edit grade information given to students at any time. Current state of Moodle Grade Center which is shown to students momentarily reflects situation in application. Which means that grade that is given through application can be views by students in Moodle immediately.

This approach enables direct control over one or more LMS and also individual control over tools and content in LMS with ability to fetch all relevant LMS and student metadata for storage in one or more repositories.

8.5 Custom DO from LMS

While storing DO from LMS (e.g. assignments), custom metadata format can be applied before transferring DO in repository.

This concept allows better management of data and connection of additional services in the future. For example student's assignments could be extracted from Word documents with LMS metadata and stored in repository with full text and custom LMS metadata search enabled. This would allow universities to have control over all content ever created in any e-learning application synchronized with repositories, with very specific custom filtering enables. We have to keep on mind that current workflows would not have to change in anyway in order to achieve this.

9 Benefits of proposed solution

Described approach enables development of grading applications for fast grading and deposition of grades and students contributions from any E-learning application into LOR.

In proposed platform LO is stored with all metadata about structure and resources of LO taken from e-learning application connected with system. For example each usage of LMS tool assignment generates LO with full description (category of the course, course name, name of the assignment, name of the lesson, professors and students names).

Since repositories also store in LO all data about each resources, therefore mechanisms could be built which would allow creation of registries of applications which could function over federated network of LO. FEDORA is example of platform that supports creation of such mechanisms through it's API as described in [19].

This could enable, for example, listing of all contributions of students from certain tool (discussion or assignment), from all courses and studies and even from variety of different LSM with sophisticated filtering options (by success, grade, topics, year, courses, professors which taught course etc.) – which is rich metadata contained in LMS.

In future versions of applications we would be focused on implementing OAI-ORE protocol options which would allow searching through each objects ReM (Resource Maps); individual assets of each LO. This would enable viewing of all applications that integrate certain DO from repository and also map of all other DO and assets used to create DO.

DO editor with integrated search could integrate all publicly available services in creation process. Individual assets of DO could be edited in DO editor and new versions of DO published on one or more LMS which have object embedded.

Proof of concept for all this options is demonstrated within our prototype application.

9.1 LO Serialization

Different LMS and LOR systems should have agreement on semantics and different types of data and metadata naming otherwise it's would be problematic to achieve such integration. Serialization offers solution to that problem.

Serialization is the process of converting an object into a stream of bytes in order to store the object or transmit it to memory, a database, or a file. Its main purpose is to save the state of an object in order to be able to recreate it when needed. The reverse process is called deserialization. Usage of serialization in PLE e-learning environments is already explored by some researchers [20].

OAI-ORE is one of the repository protocols that implement serialization in ATOM and RDF. In combination with powerful API supported by repository applications could use different LO in LOR more effectively. Serialization would enable:

- creation of persisting objects

Which enables keeping of identical model of LO in both systems (LMS and LOR) independent of internal system data structure. This also means that SCORM Sequencing and Navigation could be much easier implemented in LMS [21].

- creation of methods for RPC (remote procedure call) over web services like SOAP or REST.

By using this option data fields in LMS and LO stored in LOR could be used by different web services without usage of LMS application server.

- Creation of methods for fast update of changes in DO

LO states like graded, not-graded, submitted, not submitted etc. and other used in SCORM could be much easily implemented in LMS and LOR.

10 Conclusion

LMS daily store large numbers of LO which are frequently poorly handled in the system with week integration options.

It's normal that LMS should stay closed environments on institutional level but variety of important options are poorly or not implemented at all. Advance search across whole institution, reuse, collaboration, versioning, workflows etc. are common options which are frequently missing.

Proposed Registry of E-learning tools is example of application store that educational community deserved long time ago considering specific needs, size and activities that are surrounding it.

This paper described whole architecture with proof of concept for majority of features described in paper. Hopefully in the future we'll see more projects integrations with core LMS solutions simplifying existing and bringing many new important and necessary features.

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