Online Laboratories Embracing the Reusable Learning Objects Metaphor

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Abstract*: Reusable Learning Objects (LOs) arena is a considerably rich area of research. The area is of particular emphasize on distance and blended learning. One key issue in the LO area is the metadata. The latter is made to facilitate indexing, searching, and exchanging LOs. In this paper, it is proposed, that laboratories, particularly those equipped with online operating more, could be considered as an extension case of the learning objects metaphor. A reusability example of a three access mode process control lab has been shown, and followed by presenting how an associated IEEE standardized metadata can be generated. Further discussion of the argument is presented and is followed by concluding remarks.*

Introduction

A learning object (LO) is a resource, usually digital and web-based, that can be used and re-used to support learning. The IEEE Learning Standards Committee defines learning objects as any entity, digital or non-digital, that can be reused or referenced during technology supported learning (IEEE, 2002). In Ip et al.(2002), learning objects are defined as “a computer mediated or delivered module or unit, that stands by itself, that provides a meaningful learning experience in a planned learning context”, hence emphasizing the digital nature of learning objects. LOs are characterized with many attributes, mainly they are featured of: *Micro elements:* LOs are micro learning elements, small chunk of information that may take couple of minutes instead the couple of hours approach of learning; *Encapsulation:* LOs are self-contained and can be taken independently; *Reusable:* LOs are reusable, and they can be mutated to another courses or learning activities easily; *Aggregation:* an LO can be grouped with other LO’s or into larger learning content, course, etc.; *Metadata Description:* every learning object has descriptive information allowing it to be easily found by search engines (MERLO, 2009). The advantage of this micro design of learning materials in terms of small chunks is the usability and transferability to another related courses or learning activities with minimal modification effort. LOs will typically have a number of different components, which range from descriptive data to multimedia and information about copy rights and educational level. At their core, however, will be instructional content, and probably assessment tools. Sometimes, learning objects are described similar to the LEGO (Wiley, 2001).Learning object deployment in the tuition process has been found to bring added positive value to the learning process in many pedagogical studies (Krauss and Ally, 2005; Cook et al., 2007; Jones and Boyle, 2007). In the recent years, research and funding for LOs have considerably increased. Many services and databases have arisen, such as the specialized LOs journal “Interdisciplinary Journal of E-Learning and Learning Objects “, the web data base of LOs MERLOT, and the Reusable Learning Objects Center of Excellence in Teaching and Learning in the UK (Rlo-

CETL, 2009). A learning object is not just a piece of text or a graphic or a video clip, these elements can be used in the process of developing a multimedia LO. Also, the LO is not an entire course on a particular topic. A key issue of LOs development is the use of metadata which provides a standardized description of learning objects enabling finding the needed content when a macro learning component is meant to be built through a set of learning objects. The latter are normally stored in online repositories, metadata schemas enable exchanging learning objects metadata among repositories that admits similar schemas for representing their metadata (Najjar, 2008). Metadata is a crucial part in the digital resources lifecycle (Polfreman and Rajbhandari, 2008). Metadata can be described as being *data about data*, which is usually encoded in a XML file. Having the metadata structure, one can build a course on process control system for instance by combining related learning objects from connected repositories. There are many metadata standards that have been made available for indexing learning objects such as the Dublin Core Metadata Element Set (DCMES) (Dublin Core, 2003); the IEEE LTSC Learning Object Metadata (LOM) (IEEE, 2002 & 2005); and the Alliance of Remote Instructional Authoring and Distribution Network for Europe (ADRIANE) (Duval et al., 2001). The IEEE LOM is a widely spread standard (Najjar, 2008), in the next section, further details are introduced.

The IEEE Learning Objects Metadata (LOM) Standard

The LOM data model was proposed by the IEEE to provide a standardized way of describing and indexing learning objects (IEEE 2002 & 2005). The LOM data model specifies which aspects of a learning object should be described and what vocabularies may be used for these descriptions. It also defines how this data model can be amended by additions or constraints. The LOM is composed of a set of data elements used for the proper indexing purpose. These data elements are grouped into nine hierarchical categories:

- General: which groups data elements that contains general information about the learning object. This includes identifier, title, language, description, keywords, coverage, structure, and aggregation level.
- Lifecycle: which contains information about the learning object lifecycle such as the version, status, and the contributors.
- Meta-metadata: which contains information about the metadata. This includes, identifier, contributor (author), language, and the metadata schema used for its creation.
- Technical: which contains information related to the technical development of the learning object. This includes, format, size, location, requirement, installation remarks, duration, and other platforms requirements.
- Educational: which contains information related to the educational use of the learning object. This includes, interactivity type, learning resources type, interactivity level, semantic density, intended end user role, context, typical age range, difficulty, typical learning time, description, and language.
- Rights: which contains information about the copyrights of the learning object. This includes, rights, costs, copyrights and other restrictions, and a description.
- Relation: which contains information on the relationship between the learning objects and other learning objects (if any). This includes the following data elements, relation, kind, and resource.
- Annotation: which contains information of comments on the educational use of the learning object. It contains the following data elements, annotation, entity, date, and description.
- Classification: which contains information on how the learning object is classified within a specific domain. This includes, classification, purpose, taxon path, description, and keywords.

The LOM data elements are classified into two main types, aggregate data elements that contains other sub-elements and do not have values themselves, and simple data elements that contains data which could be single or multiple. The properties of the simple data values are also specified within the LOM standard. The LOM is a generic standard which also can extended or adapted, this can be done through a specific modification described in the standard. The customized versions of the LOM are called "application profiles". Building a metadata profile that conforms to the IEEE LOM is exhaustive and a time consuming process (Najjar, 2008; Polfreman and Rajbhandari, 2008). This has been reported to be a restriction factor of metadata generation by the learning objects authors, limiting the LO searchability and outreach. Hence a couple of automatic metadata profile generation have been developed. Automatic generation tools was reported to be the cure of the metadata generation bottleneck (Polfreman and Rajbhandari, 2008). One of these tools that developed for the IEEE LOM standard is the LomPad (LomPad, 2009). LomPad is an open source java based tool, it is bilingual (English/French) and enables the user an easy way of deploying LOM based metadata in their learning objects. The tool interface is shown in Figure 1. There are nine main pages, each of them is dedicated to one of the main LOM categories. After filling the data, the user can view the metadata file either in HTML or in XML format. After saving the metadata in XML, it can be deployed on the web in the specific webpage related to the learning object.

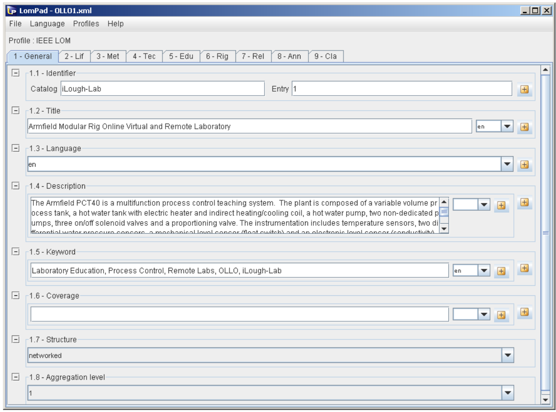

Figure 1: The LomPad automatic IEEE LOM metadata generation tool

The Online Laboratory Learning Object (OLLO)

There has been recent shift in engineering education towards embracing constructivist pedagogy and experiential learning practices. There is more demand on supplementing the theoretical lectures in the engineering courses with authentic real applications, i.e. laboratory demonstrations. Additionally, more and more engineering institutes embed project based learning practices in their curricula, which implicitly require extra laboratory resources. However, due to the costs involved in building and running laboratories it is not feasible to supply large number of laboratory experiments for each single taught course, many institutions have reduced their capital spending on laboratory equipments (Magin and Kanapathipillai, 2000). Furthermore, successful operation of a laboratory experiment usually requires considerable teacher tuition effort for both the conceptual profile of the experiment as well as the hardware operations. Many of the previous obstacles can be overcome by developing a self-contained entity that includes instructions and information about the experimental rig, the hardware operation, the purpose of the experiment, a brief background of the theory, simulation of the rig, and an experimental procedure for the sake of learner-centered approach of conducting the experiment. Additionally, the remote operation capability of the hands-on lab allows sharing the whole entity and the lab rig among different institutions, which could result in dramatic drop of the cost of setting up new labs and will considerably enrich the engineering pedagogy by embedding new laboratory resources that would not have been possible to access. Furthermore, remote labs on have been reported as an enablers of distance education of engineering degrees (Bourne et al., 2005).An online laboratory entity as described before can be called the "Online Laboratory Learning Object", or in brief OLLO. In definition, the Online Laboratory Learning Object (OLLO) is a learning object that is particularly designed for the laboratory pedagogy and is characterized by the following: (a) It is a learning object which includes self contained learning content related to the hands-on laboratory experiment that enables learner-centered approach of learning the experiment; (b) It contains a standardized metadata for indexing and searching purposes; (c) It is incorporating remote operation of the physical hands-on lab rig, mainly through the internet; and (d) It is designed to mimic a relevant hands-on laboratory when operated offline by using virtual instrumentations. The OLLO without remote operation of the physical instruments is a learning object LO only and is NOT an OLLO. Each engineering department have many laboratories which their access is limited to the department's staff and students mainly. The benefits of developing OLLOs for as much labs as available within the institute is not only limited to the teaching and learning process, a collaborative research could be significantly fostered when such large database or repository of OLLOs is easily findable and accessible. For further enhancing the collaborative part of an OLLO, video conferencing and editing tools can be added on the top of the OLLO.

Reusability Case of the Loughborough Process Control Lab

The lab aims to introduce the students to the principles of control engineering, such as the main components and instruments of a feedback loop, the concepts of open-loop control, feedback control, proportional-integral-derivative (PID) control, and PID controller tuning. The lab can be used for (a) calibration of the level sensor, (b) calibration, hysteresis detection, installed characteristics and relative resistance of the control valve (c) to develop an appreciation of automatic control vs. manual control, (d) to obtain a qualitative grasp of the differences among, proportional controller (P), proportional-integral controller (PI), and proportional-integral-derivative controller (PID), (e) to develop rules for control structure selection based on the observed qualitative information, and (f) to perform automatic controller tuning. A virtual version of the lab has been developed and it was made available to students for download from http://www.ilough-lab.com. The Process Control Virtual Laboratory allows students to perform experiments in a simulation mode using an interface identical with the real operator interface in the laboratory. Remotely operation capability of the lab has been developed also and many rigs can be accessed remotely through the www.ilough-lab.com portal.

Table 1: Reusability Example of the Loughborough Process Control Lab.

Curriculum Year	Module	Academic Year (2007-2008/2008-2009)		H*	V*	R*	Objectives
1	Process Balances	x	x			x	Dynamics
2	Instrumentation and Control	x	x	x	x	x	Control/Instrumentation
3	Process Control		x			x	PID** tuning
MSc	Adv. Comp. Meth. for Modeling and Analysis of Chem. Eng. Sys.	x	x	x	x	x	PID theory

*H (Hands-on), V (Virtual), R (Remote). **PID (Proportional, Integral, Derivative controller)

Generally speaking, laboratories are reusable objects. Many laboratory rigs are multifunctional enabling offering different experiments for different courses at levels. With a single functioning laboratory rig, different aspects of the dedicated experiment can be exposed for different level audience. An experiment offered remotely, is inherently reusable since it can be shared and adopted for showing the application of theory in courses of similar level but conducted at different universities. Different aspects of the Loughborough process control rig has been used for courses in the first, second, and third year undergraduate courses at the chemical engineering department of Loughborough university. The experiment has been also used in an MSc course teaching in the department. Different aspects of the experiment have been used in different contexts and at different academic levels. The remote and virtual versions of the lab enabled utilizing it in an innovative and unconventional manner such as reported in (Abdulwahed et al., 2008; Abdulwahed and Nagy, 2009). This represents an example of the high reusability potentials of one experimental rig such as summarized in Table 1. Many software platforms have been used for developing LOs such as Flash, Photoshop, and web design tools. However, the OLLO is considerably of much more complex structure than the normal LOs due the factor of incorporating physical hardware in the LO and the fact that the laboratory rig should be operated remotely through the internet. The latter requires onsite Data

Acquisition (DAQ) and hardware interfacing, automated operation, web server installation, software interface, and web interfacing. An OLLO also requires designing automated virtual instrumentation simulation of the real rig. LabVIEW, a commonly used application software in the industry and academia, provides a flexible and rich environment for developing the OLLOs. LabVIEW is modular in the sense that individual modules can be easily developed and added the application, it is compatible with legacy code that could have been written in Matlab/Simulink, or C; it is compatible with wide set of hardware devices, it has advanced debugging features, and very intuitive graphical user interface GUI, and furthermore it can integrate multimedia. The Loughborough process control lab OLLO has been developed with LabVIEW, live video transmission has been developed to emphasize the remote experiment authenticity. The metadata file was generated with the LomPad tool and is to be integrated in the lab page. A sample code of the first lines of one of the Loughborough process control lab rigs, the Armfield rig, is shown in Figure 2.

```
<?xml version="1.0" encoding="UTF-8" ?>
<lom xmlns="http://ltsc.ieee.org/xsd/LOM"
xmlns:xsi="http://www.w3.org/2001/XMLSchemainstance"
xsi:schemaLocation="http://ltsc.ieee.org/xsd/LOM
http://ltsc.ieee.org/xsd/lomv1.0/lom.xsd">
 <general>
- <identifier>
<catalog>iLough-Lab</catalog>
<entry>1</entry>
</identifier>
 <title>
<string language="en">Armfield Modular Rig Online Virtual and
Remote Laboratory</string>
</title>
<language>en</language>
```

Figure 2: A sample code of the Arnfield rig OLLO metadata file conforming with the IEEE LOM standard

Discussion

We argue that labs should embrace the learning objects metaphor because labs themselves are self contained learning chunks which are provided as supplemental (or stand alone) support for understanding theory. Furthermore, in many cases, a laboratory experimental rig can be used in different courses and in different contexts. The latter two characters are inherent in the learning objects philosophy. For instance, a control experimental rig can be used for a control course that is taught in chemical engineering, mechanical engineering, or electrical engineering. The process control rig can be used as experimental rig in a control course, or in modelling course. Laboratories are often developed for providing the students with authentic real experience, if we restrict the OLLO for simulation only as the case of many LOs, the developed laboratory learning object will loose the most important motivation behind labs tuition, which is realism. Embracing the learning objects metaphor will introduce the laboratory development and educational research into a rich arena. Research, either on the development level, the portability, the outreach, the usability, or the pedagogy of learning objects is active and is attracting considerable amount of funding. When labs are considered as an extension of the learning object metaphor, research findings and development tools applied on learning objects can be adapted and extended to the laboratory education field. More and more systems rely on some metadata standard for facilitating sharing and exchange of content and metadata (Duval, 2004; Rehak, 2003). Laboratories, in particular online labs, are seldom to have a standardized metadata describing their character, furthermore, we argue that there is no existing repository of online labs which limits to large extend finding, exchanging, and deploying remote labs in the sense of learning objects does.

Conclusions

Laboratory education is a central part in engineering and science education. Laboratories give a chance for developing student-centred learning activities, and to foster experiential learning. Labs can be used in different courses, and experimental rigs can be used for demonstrating different experiments. Yet, labs are expensive tools for academic institutions, they are limited to access, and often they cannot be synchronized properly with the progression of the taught material in the lectures. Online labs equipped with the concept of learning objects can provide a solution for reusability and enriching education with multi style and sharable chunks of learning materials. In this paper, a reusability example of a three modes (virtual, remote, and hands-on) process control lab has been introduced. Additionally, it has been shown how the lab was further developed to dress the learning objects metaphor emphasizing on the metadata key aspect of LOs. It is suggested that considering the suggested OLLO model would introduce the laboratory research and development into a rich area, the LO, which has particular importance for distance and blended learning.

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