

# Towards the loose coupling between LMS and Remote Laboratories in Online Engineering Education

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**Abstract**— In this paper, we are providing a study on the issue of interoperating Learning Management Systems (LMS) and Remote Laboratories, in a seamless integration. This study emphasizes the need to make Remote Laboratories seen as a pedagogical material within the LMS. We are presenting a novel and original approach to make these two types of platforms communicate (LMS and Remote Laboratory) under a loose coupling relationship. The main purpose of this work is to bring a better follow-up of students to the tutor and the students themselves, and therefore to lead to an enhanced learning experience. (Abstract)

**Keywords**- Remote Laboratories, Distance Learning, Learning Management System, Interoperability, Learning experience, Hands-on Approaches, Personalized Learning, IMS-LD, SCORM.

## I. INTRODUCTION

Remote training services exploded with the growth of the Internet. Information Technologies and Telecommunications appeared therefore as a keystone for the leverage of Remote Laboratories (RLabs) in Distance Learning curriculum. Before the last few years, ongoing research in Distance Learning primarily focused on conceptual teaching or case studies, in the form of remote courses, works directed remotely or remote projects, but without possibility of real practical activities.

Hands-on approaches however are mandatory in scientific and technical education, especially in engineering curriculum [1]. Mainly, this study emphasizes that hands-on approaches help the students in making the link between theory and real problems, in supporting motivation and curiosity, in contributing to their personal development, in building socials

networks. Because heavy and expensive industrial et laboratories facilities can neither be moved nor easily duplicated, a lot of efforts were made for the development of platforms, which now allow remote interactions between geographically distributed users and a pedagogical materials hosted in the school [2,3,4,5], laboratory [6] or company walls [7]. In these publications, all researchers accord to observe that it is not enough to create an interactive Web Site: it is compulsory that the conditions of experiments are realistic, productive and protected. In Distance Learning, one could add that interoperability is another mandatory characteristic, as Learning Management Systems (LMS) are the containers of remote learning activities and student's follow-up, and they are not yet able to include remote hands-on activities, while they already host lectures, tests, etc. Remote practical works are therefore ignored, because excluded since of their low interoperability, from the LMS. This paper addresses the problem.

In this paper, we are primarily interested in the interoperability between any Learning Management System and any Remote Laboratory. We identify the LMS as the element in the Information System that endorses the role of exposing the teaching contents on line while ensuring the follow-up of the user learning throughout his course of study. The purpose of this article is therefore to propose new models of interactions between these two types of platforms (LMS and Remote Laboratory) for a better follow-up of students, and therefore an enhanced learning experience.

The paper is organized as follows. Section 2 introduces a presentation of LMS in the light of relevant elements for integration with Remote Laboratories. Section 3 presents some

elements of today's architecture for most common Remote Laboratories. Section 4 presents our approaches to make the two previously exposed architectures interoperate. Section 5 concludes.

## II. LEARNING MANAGEMENT SYSTEM (LMS)

In order to face problems in Education and life-long learning, such as the fast evolution of pedagogical materials and contents, many institutions and companies have turned towards e-learning, which makes it possible to learners, to acquire knowledge and competences without having to move of their place where they live or work. This calls the citation from Jesus del Alamo: "If you can't come to the lab, the lab will come to you" [8]. In order to facilitate the organization and the success of these new ways of learning, software solutions appeared, known as "Learning Management Systems" (LMS). LMS are platforms created for managing remote curriculum and teaching through the Internet, while also proposing an electronic follow-up of the students throughout their learning experience.

The LMS are Web applications, which provide to their users (designer, tutor, learner, coordinator, and system administrator or super user), a set of tools ([9], [10], [11], [12]), or services allowing especially for:

- The designer:
  - To build and maintain his/her pedagogical materials by integrating resources and activities of any type according to a hierarchical structure carried out according to the standards, mainly at the SCORM (Sharable Content Object Reference Model [13] or IMS-LD (Instructional Management Systems-Learning Design [14])).
- The tutor:
  - To organize the groups of training and to determine the parameters and the processes of the training sessions.
  - To carry out the follow-up of the students.
- The learner:
  - To reach and follow courses according to their own rhythm, auto-evaluation using tests constructed and carried out according to IMS-QTI specifications.
- Both the tutor and learners:
  - To communicate in a synchronous way (chat) or asynchronous (mails, forum, shared documents).

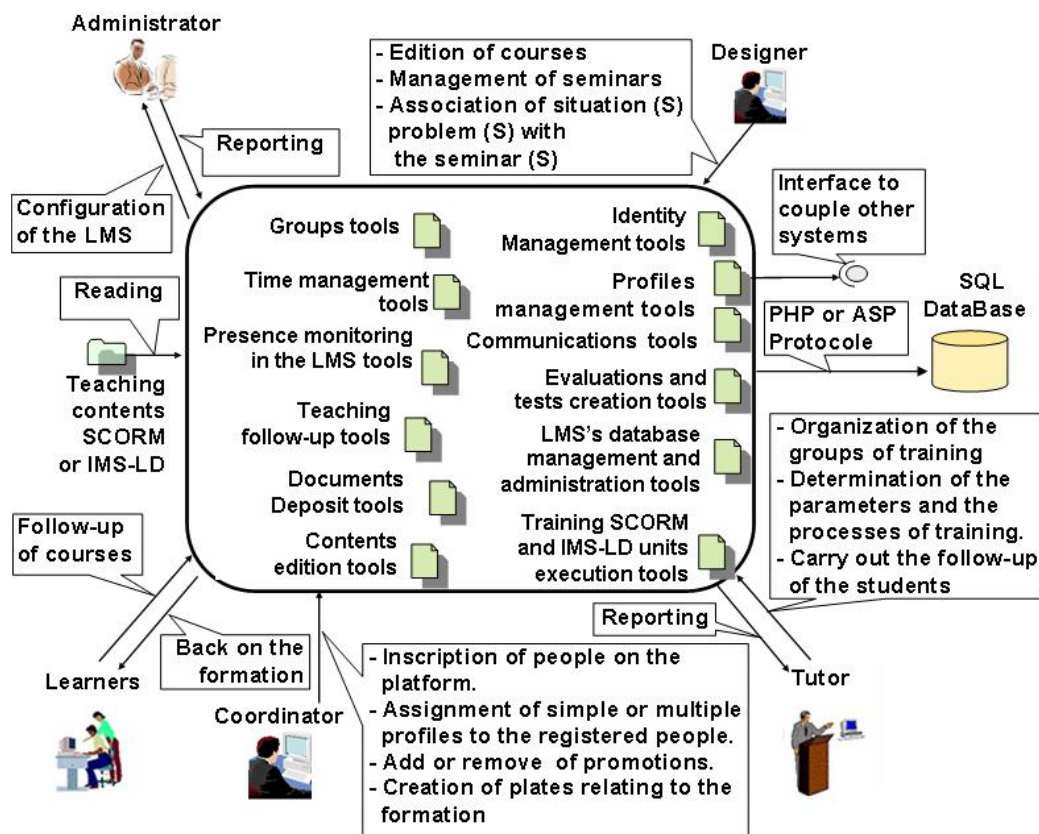


Figure 1. Figure 1 : LMS's components and Functioning principle

- The coordinator:
  - To register people on the platform.
  - To assign simple or multiple profiles with the registered people.
  - To add or remove of promotions.
  - To create areas relating to a module of training.
- The administrator:
  - To configure the platform according to the desired organization.

The Figure 1 shows the common most frequent components, which can be met, in a given LMS, as well as the functioning principle of this last one.

### III. REMOTE LABORATORIES

The remote laboratories are referring to practical works carried out remotely on real devices under the assumption of a learning experience. Learners, tutors as well as devices to be handled are not in the same place. A typical architecture for the remote laboratories is given on figure 2.

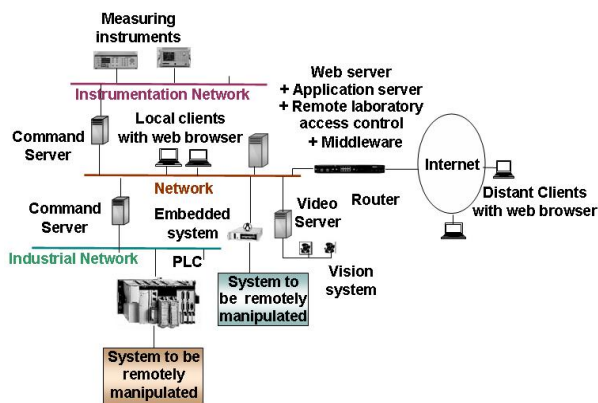


Figure 2. Figure 2: Typical Remote laboratory structure

The common software architecture is composed as follows (figure 3): the device itself, a local computer connected to the device, which plays the role of a gateway between the device and the remote computer of the user, and the associated middleware, through which information is exchanged between the local and the remote computers. There is, of course, a reason why this architecture is so widespread. In fact, most of devices must be locally handled by a computer in order to be remotely controlled over the Internet. There is no denying that some device directly embed an Internet connection, but this is only because they embed a modern operating system inside the device, which therefore does not require a dedicated local computer; yet it does not make much difference in the presented architecture: local computer (would it be embedded in the device itself or as a separate computer linked to the device, middleware, and remote Graphic User Interface (GUI)).

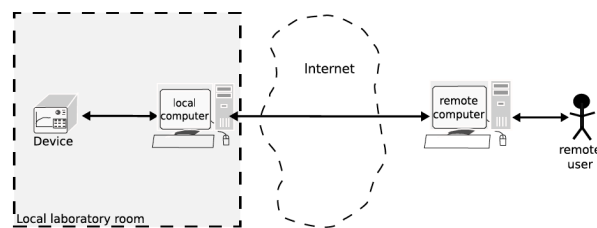


Figure 3. Figure 3: The widespread software chain of remote laboratories.

but to build a middleware allowing remote clients to connect to the local computer that handle the device. That is the reason why the first remote laboratories were using software solutions such a VNC1, as it provided them the remote control over the local computer connected to the corresponding device. Nonetheless, those solutions were given up as they lack security and they require a lot of bandwidth, in favor to software development following the Distributed Architectures paradigms, such as Service-Oriented Architecture.

This evolution was mandatory to open the Remote Laboratory middleware to the other services in the Information Systems, and especially to Learning Management Systems, as we will study it under the following section. The connection between LMS middleware and RLabs middleware is at the core of our approach.

### IV. A NEW APPROACH TO COUPLE A LMS AND A RLABS.

As already evoked in section 2, many institutes have already included remote formations in their curriculums. However, these platforms, largely used today, are not designed to integrate remote practical works, whereas remote practical works propose to put the theoretical teaching into practice, they are found excluded from the LMS, for lack of sufficient software technologies. The fact that the RLabs session is unlinkable to a Learning Object in the LMS at the moment comes with strong drawbacks:

- all the situations of training are hardly proposed online, and especially,
- no follow-up of students can be proposed during remote hands-on approaches,
- no authoring tool for setting-up the associated learning scenario,
- no possibility for the student to easily confront experimental results towards his/her theoretical exercises conducted in his/her LMS session.

It has to be noticed that especially the latter one (decreasing the learning enhancement by putting technological barriers between theoretical and practical learning experiences) strongly violate the first principle of laboratories in general,

<sup>1</sup> Virtual Network Computing

which are designed to let the students making theory and practice meet during the same learning session.

We therefore think that part of ongoing research in R Labs should focus on making R Labs and LMS converge. The gap [13] between platform of remote practical works and the LMS is due to the fact that remote practical works require specific developments. They are thus stored in platforms' owners, while no standard exist for R Labs. As for LMS standards, such as SCORM [14] or IMS-LD [15], nothing is designed for R Labs, because so far those standards did not excepted the pedagogical content to be hosted outside the L(C)MS2. Moreover, it is difficult to imagine to host all the remote practical works in a LMS, in the same way that lectures or directed works, which requires much less interactivity between learners and educational contents.

This said, a pragmatic solution to integrate R Labs within an LMS, would be to carry out a loose coupling, between these two platforms through an interface in the forms of modules or "plug-ins", allowing to connect any R Lab to any LMS, as long as the shared vocabulary and data exchange protocol (the module of the LMS, and its correspondent for the R Labs) is available on both parties.

Our research tasks thus initially concentrated to make a research on the platforms of LMS having a plug-in system. After a long bibliographical search we discovered that there do not exist academic documents covering this kind of subject. In practice existing LMS (e.g: Moodle, Claroline, etc.) allow the use of third-parties libraries through a plug-in system.

One can afterwards recover information on the set of "widgets"  $W = \{w_1, w_2, \dots, w_n\}$  used in the remote GUI of a R Lab (whatever the technology of the R Labs). It is therefore possible to store the set of widgets of each R Lab in a repository, which could be queried afterwards, so that the remote GUI could be instance on the fly, after the set of widgets delivery. If this set of widgets is hosted in the LMS and seen as usable resource in learning scenario in LMS, the connection between LMS and R Labs become effective. Indeed, the LMS have the knowledge and comprehension of the widgets, and the R Labs is built upon instantiation from the widgets retrieved within the LMS. The widgets are therefore the keystone for interoperability between LMS and R Labs.

In this study, the aim was not to reinvent the wheel as for a widget repository for R Labs. [16], [17], and [18] proposed an architecture which make it possible to display a set of "widgets" by making an entry from a Unit Of Learning (UOL) in the IMS-LD standard. Thus while proceeding to small improvements of this architecture, we think that it is possible realizing the development of some modules and "plug-ins" of extensions, to use it as bridge or interface to couple in loose manner, an LMS and a remote "Widgets Laboratories".

<sup>2</sup> Usually the difference is made between the LMS, which expose pedagogical content to the students and tutors, and the LCMS, meaning Learning Content Management Systems, which is held responsible for providing authoring tools and scenarii engines. In this paper, we are using the stretch of language where LMS denotes both the LMS and the LCMS.

Thus, this is the approach, which we try in this research project, to realize by proposing a new architecture allowing to remotely controlling a system via its deported GUI, made up by a set of "widgets".

A study of the functioning of "Wookie" [18], showed us that it is possible to make this coupling while making:

- An entry from a UOL (Unit Of Learning) IMS-LD according to the architecture of figure 4.
- A simple entry (i.e. not from an IMS-LD scenario) from the LMS according to the architecture of figure 5.

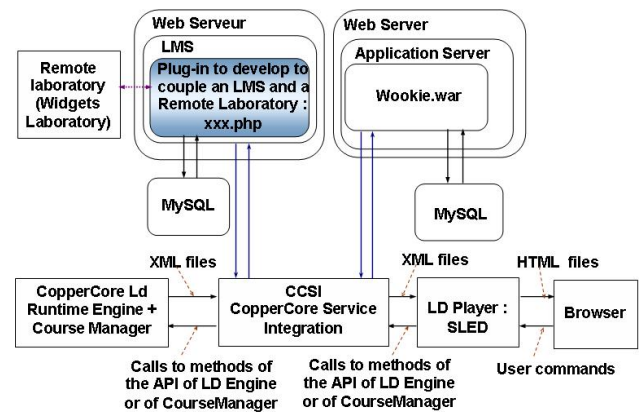


Figure 4. Figure 4 : LMS Remote Laboratory Coupling with an entry from an UOL IMS-LD

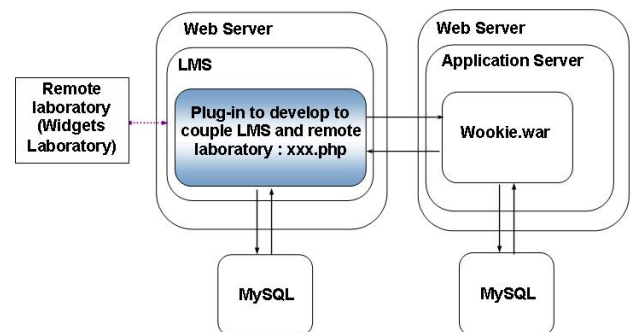


Figure 5. Figure 5 : LMS Remote Laboratory Coupling with a simple entry from the LMS

The Plug-In, in these two architectures carries out the two following principal operations:

- Request "Wookie" to have an instance of the "Widgets" to deploy in the LMS to command the instrument or the system,
- Parse the response sent by "Wookie" to create a GUI of the command of the instrument or system in the LMS.

We chose in a first step to work within second architecture assumption, by leaving an entry from a IMS-LD scenario in second step, as it lead us to use all the chain composed by : SLED, CopperCore, and CCSI ([19], [20], [21]).



Wookie responds to request (GET request for a widget/set of widgets instance) by sending a response in XML form, about information relating to the “widget” or the whole of the “widgets” for which it was requested.

Typical responses from the Wookie server is as follows:

- For one widget:

```
<?xml version="1.0" encoding="UTF-8"?>
<widgetdata>
<url>http://localhost:8080/wookie/wservices/www.getwookie.org/widgets/W
P3/natter/chat.htm?idkey=Mtw6vPPVApb6kbJukBbFXQzEPuw.eq.&pr
oxy=http://localhost:8080/wookie/gadgets/proxy&st=0%3Atestuser%3A
http%253A%252F%252Fwww.getwookie.org%252Fwidgets%252FWP3%25
2Fnatter%3Awookie%3A%252Fwookie%252Fwservices%252Fwww.getwoo
kie.org%252Fwidgets%252FWP3%252Fnatter%252Fchat.htm%3A0%3AMt
w6vPPVApb6kbJukBbFXQzEPuw.eq.</url>
<title>Natter</title>
<height>383</height>
<width>255</width>
<maximize>>false</maximize>
</widgetdata>
```

- For a set of widgets:

```
<?xml version="1.0" encoding="UTF-8"?>
<widgets>
<widget id="http://www.myhost.org/widgets/default/chat">
<title>Chat</title>
<description>This widget provides a simple chat or
Instant messaging facility</description>
<icon>http://localhost:8080/wookie/shared/images/chat.png</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget id="http://www.myhost.org/widgets/default/forum">
<title>Forum</title>
<description>This widget provides a threaded
discussion forum facility</description>
<icon>http://localhost:8080/wookie/shared/images/forum.png</ico
n>
<parameter>widget=unknown</parameter>
</widget>
<widget id="http://www.myhost.org/widgets/default/vote">
<title>Vote</title>
<description>This widget provides a voting
facility</description>
<icon>http://localhost:8080/wookie/shared/images/vote.png</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget id="http://www.getwookie.org/widgets/weather">
<title>Weather</title>
<description>A silly Weather widget</description>
<icon>http://localhost:8080/wookie/wservices/www.getwookie.or
g/widgets/weather/icon.png</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget id="http://www.getwookie.org/widgets/WP3/natter">
<title>Natter</title>
<description>basic chat widget</description>
<icon>http://localhost:8080/wookie/wservices/www.getwookie.or
g/widgets/WP3/natter/icon.png</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget id="http://www.schulz.dk/pacman.xml">
```

```
<title>PacMan v2.6</title>
<description>Google Gadget</description>
<icon>http://localhost:8080/wookie/shared/images/defaultwidget.p
ng</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget
id="http://www.labpixies.com/campaigns/clock/mini_clock.xml">
<title>LabPixies Clock</title>
<description>Google Gadget</description>
<icon>http://www.labpixies.com/campaigns/clock/images/mini/th
umbnail.jpg</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget
id="http://www.labpixies.com/campaigns/todo/todo.xml">
<title>ToDo</title>
<description>Google Gadget</description>
<icon>http://www.labpixies.com/campaigns/todo/images/thumbnai
l.jpg</icon>
<parameter>widget=unknown</parameter>
</widget>
<widget
id="http://www.labpixies.com/campaigns/weather/weather.xml">
<title>Live Weather</title>
<description>Google Gadget</description>
<icon>http://www.labpixies.com/campaigns/weather/images/thum
bnail.jpg</icon>
<parameter>widget=unknown</parameter>
</widget>
</widgets>
```

As for authoring of the RLabs possibly connected to a LMS, the process is to describe a set of widgets in the Wookie fashion, setting a package for “Wookie” [23], and then to use it as a UOL in the learning scenario hosted by a LMS compliant with IMS-LD. This also means that the RLabs is reusable through different LMS, as long as it supports IMS-LD standard (loose coupling).

However, while processing in this way, there is not enough loose coupling, in our opinion. The main issue is that Wookie repository of widgets is populated from its config file describing the widgets (a set of widgets according to the W3C standard with its file config.xml, containing the URI of the start page as well as metadata, and loaded in “Wookie” via the its admin pages of this last one [22]). This is however compulsory if we want to connect an existing RLab to Wookie without having to reengineer its widgets. In order to solve this problem, we think that it is possible to modify the source code of “Wookie”, so that it could import these informations from the RLabs itself. A first simple solution consists in introducing these informations directly into the database of “Wookie”. Another solution is under study as we are conducting research in this matter, and especially using the Web 3.0 (ontologies) to represent the GUI of a RLabs in our RLabs framework (called OCELOT [23]). Such ontologies could be aligned with the concepts and relationships proposed by Wookie so that the widgets issued by such a framework could automatically be populated in the associated wookie meta-widget representing the RLabs, and allowing the connection with the LMS thanks to IMS-LD.

## V. CONCLUSION

In this paper, we tried to a new approach which tries to close the gap between LMS and RLabs. The main issue is to find a solution to use the RLabs in the UOL (Unit Of Learning), conform to standard IMS-LD, so that the walkthrough of the student during RLabs session could participate to the LMS follow-up of the student.

The main result is a loosely-coupled approach based on existing software which allows the follow-up of students during RLabs sessions through their use of predefined widgets expressed in a Wookie server, which are themselves usable in a UOL in IMS-LD standard. The biggest open issue is the provisioning of the Wookie server. Several means are under study, from standard insertion in database, to automatic provisioning through ongoing research in ontologies alignment, but each of these should still be tested in a real experiment in a broader audience in order to gather data on their scalability. Future works will consist in studying different granularity of expression for the widgets, in order to refine the follow-up of students during RLabs session in their learning walkthrough, so as to as better learning experience could be delivered to both the students and the tutors.

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