Extending LMS with Collaborative Remote Lab features

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In university education, classroom activities are more and more combined with on-line teaching materials, webinars, electronic forums, wikis, web calendar and so on. This "blended approach" is often based on the adoption of Learning Management Systems (LMS), which are customized in many aspects to match both the teaching style of the university and the needs of teachers and students. More recently, also laboratory experiments, that are integral parts of science and technology classes, have come on-line. The first generation of Remote Web Laboratories (RWL) has demonstrated the feasibility and the effectiveness of on line experiments, with two major drawbacks: the lack of integration between LMS and RWL and the lack of synchronous interaction among the participants (teacher and students) to the experiment. In this scenario, the paper discusses the principal aspects and the main results about an integration project between the Moodle LMS and the MicroNet RWL at University of Salento, in Italy.

Keywords: 3.0.b Collaborative Learning Tools, 3.2.b. Computer science education, N.1.d Virtual Labs, 5.3.h Web-based interaction

I. INTRODUCTION

Online engineering education has been strongly enhanced after Bologna Declaration, which has contributed to shift the learning focus from the institution to the student [9] and has remarked the ''learning by doing'' using laboratories [10]. Distance learning has brought to the Web a number of learning tools, making lectures possible where teachers and learners are in different places and/or at different time. Moreover a geographically distributed classroom leads to create virtual environments, where we try to recreate the process of learning in a group ([3]).

Distance learning is mainly based on the use of Learning Management Systems (LMS), whose aim is to support the creation of courses catalogues for groups of students, to enable their assessment by the teacher/lectures, to permit the virtual interaction among participants (students and teachers) by means of both synchronous (i.e. chat, videoconference, …) and asynchronous (i.e. whiteboards, forums, mailing list, etc.) collaboration tools.

The learning scenario they usually support is that of a traditional lecture, where a teacher lectures a lesson to a group of students. This model is not adequate when learners need hands-on approaches in order to obtain the knowledge on how lab equipments are supposed to be manipulated. Currently the integration of LMS and Remote Labs has become a hot topic among researchers investigating technologies for learning.

Actually, technology enabled labs include different kinds of experiments. We can distinguish among remote, hands-on and simulated laboratories ([2]) and a large debate is still going on addressing the critical issue of whether remotely operated or simulation-based labs are as effective as the traditional hands-on lab format [26].

In [21] remote labs experiments are further distinguished in batched experiments, interactive experiments and sensor experiments. Sensor experiments are those in which users monitor or analyze real-time data streams without influencing the phenomena being measured. With batched experiments, the student interacts indirectly with an experiment through a client on their remote machine, which passes the student-configured experimental parameters to the service broker, which in turn communicates to a laboratory server which executes the experiment. Ultimately the results are returned to the client once completed. In this form of experiment there is no interaction between the client and the experiment whilst it is executing. Students receive results only on completion of the experiment (indeed they need not even remain logged-in whilst the experiment request is queued or executing). Conversely, interactive experiments allow direct communication between a student's client and the laboratory server.

Our experience with remote labs focuses on interactive experiments. Our objective is to have a networked laboratory reproducing the best aspects of hands-on experiences. We believe, in particular, that collaborative aspects are essential to reinforce the interaction among the learners: the distance laboratory must foster active learning and comprehension construction by the student. In the social setting of the in-lab experience, the learner interacts directly with other students, the instructor, equipments, activities and other elements. These interactions guide interpretation and construction of concepts. They are key aspects of the laboratory experience that must be included in distance education laboratory experiences as well [6].

In this scenario the WeCoLab architecture [25], which is the foundation of the MicroNet and the AstroNet Collaborative Remote Labs, is an interesting tool to enable the synchronous collaboration among students in remote laboratories, but it is still only a component of a more

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complex learning scenario which must includes an LMS like Moodle for management, planning, provisioning and assessment of the virtual engineering classes. Moodle, in fact, is one of the most popular open source LMS, it supports many of the features above described and can be extended by means of plugins, so the integration of Moodle and Remote Web Labs (RWL) can be an interesting research theme (to this date – January 2010 – Moodle doesn't officially support any plug-in for integrating remote labs).

In this scenario, the paper discusses the principal aspects and the main results about an integration project between the Moodle LMS and the MicroNet RWL at University of Salento, in Italy. The integration approach starts from the definition of the learning scenario and its system requirements

Because of the maturity and functional extension of current LMSs platform and, with the aim of not reinventing the wheel, after the gap analysis to fit the requirements with the LMS and other components functionalities, we have integrated the different systems and discussed the main results.

The paper structure is: section 2 tracks the research foundations, section 3 describes the WeColLab architecture and user interface. Section 4 discusses the integration project and concludes the paper.

II. BACKGROUND

Remote laboratories target a large range of devices, from different scientific areas. This means that they are not restricted to a single educational topic, but they are being used with several devices and experiences that can be controlled using a computer ([2], [8]).

Since 1996 ([5]) remote labs have been increasingly popular and their development has mostly been driven to assess the technical feasibility of different approaches. As the remote laboratory platforms are getting mature, we observe that they are still built without a shared interoperable approach ([4] - [7]). Currently researchers have fruitfully investigated about how to make platforms more and more distributed, interoperable and scalable; several papers have appeared describing the use of service oriented architecture and web services to Remote Labs domain. This paradigm is used to expose the functionality of instruments ([19], [20]) and to compose measurement workflows in a multilevel architecture that enables high flexibility, scalability, and interoperability ([21], [22]).

A new EC-founded project, LiLa (Library of Labs, 2009-2011) [20], initiated by University of Stuttgart, aims at developing an integrated platform for remote experiments and virtual laboratories. It provides learners and lecturers means to search for remote experiments and virtual laboratories, perform them through a 3D integrated web portal enabling their collaborative use. LiLa reuses BW-eLabs [24] open source framework dedicated to complex experiments (initially dedicated to nanotechnologies) and based on Web Services and Semantic Web technologies.

The most popular example of distributed architecture for remote labs is iLabs ([23]), developed at the MIT. Here the equipment is managed by Lab servers, and authentication and access is moderated by a service broker. The architecture incorporates a modified Interactive Service Broker (ISB) which provides a scheduling feature and (at the appropriate time) establishes communications between the student-side client and the Laboratory server. The most recent iLabs Shared Architecture (ISA) has very strong support for access booking, distributed and federated user account management, and is inherently scalable but it doesn't support (in the current production releases) aspects such as synchronous multi-user collaboration and communication, integration with third-party learning management systems, or virtual world (3D) interfaces.

Conversely, as recently discussed in [17]; most existing LMSs support rich functionality, much of which is highly relevant to remote laboratories (i.e. grade tracking, collaboration tools, management of assessment tasks, etc), but, as [12] reports, research to integrate Remote Labs into LMS has been slowed by the fact that LMS were usually closed proprietary software systems that are often not customizable at all. This explains why the research carried out by scientists to provide laboratories has focused on means of tele-operating systems, rather than on integrating them into standard E-Learning platforms. Luckily in the last few years free and open-source LMSs have appeared (like Moodle [1], Caroline [2], etc.) which also provide interface mechanisms that allow programmatic interaction from other applications. It is therefore feasible to implement aspects such as: automated transfer of experimental results into students' LMS accounts; utilization of the LMS collaboration tools to support interaction within the experiment; assessment activities that involve live interaction with laboratories; and adaptation of the experiment based on information on the student provided from the LMS ([11], [13]).

Research literature already shows experiences of integration between LMSs and remote labs. The research lines are several: for example in MARVEL[3] pilot project, financed by the Leonardo programme of the European commission [15], Ferreira et al. [14] developed a booking system integrated with Moodle LMS. It is designed as an extension of Moodle, requiring the laboratory manager to use this LMS, even if the activity is not part of a distance learning class. Moreover it seems to be designed to reserve one only equipment per learning activity and it is not evident how it can be scaled in the case of the reservation of virtual workbenches, made up of tools distributed in different remote laboratories. Gravier et al. [16] use ontology both to describe the user interface of remote labs and to orchestrate CSCL experience, but it is not clear whether a synchronous collaborative learning experience is supported or the

[1] See http://www.moodle.org

[2] See http://www.claroline.net/

[3] MARVEL: Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning

platform only enables students' sequential access to lab equipment.

Remote lab's learning experience is based on IMS-LD standard in order to be executed by an appropriate engine and been shared among different remote labs ([18]).

A further research trend focuses upon investigating how recreate the conventional proximal labs interactions among students in virtual environments. Being able to "eavesdrop" on related conversations, notice the issues confronting other students, and overhear the questions they are asking the instructor, can all play a role in assisting the learning process. Partly, this is a design issue – being able to construct interfaces which expose peripheral activities, but it is also a technological issue – in terms of how this rich set of information can be structured and presented to users without it being distracting. An example of this kind of system is described in [25], where virtual classrooms can share distributed lab equipments in an integrated synchronous collaborative environment.

III. EVOLVING LMS WITH REMOTE COLLABORATIVE LABS: A LEARNING SCENARIO

Engineering and scientific classes combine face to face and laboratory activities. More and more both of them are delivered and/or supported by on-line teaching materials, webinars, electronic forums, wikis, web calendars and, recently, Web Labs. This "blended approach" is often based on the adoption of Learning Management Systems (LMS), which are customized in many aspects to match the learning style and the needs of students.

The management of these classes is more complicated than traditional face-to-face scenario, since it involves more actors in the development and provision of the learning activities. At least they include lecturer, lab equipment manager and IT technical support for the management of IT systems (typically LMS platforms).

The learning scenario we envision considers the development, provision and assessment of a traditional academic course (for example the "Measurement Methods" class) with the support of virtual tools (calendars, forums, online learning materials, etc.), which also enable students to meet online and to make the experiments assigned as home-works in a synchronous collaborative environment. Typically the tools are integrated in an e-learning environment, supported by an LMS.

In this scenario the teacher/lecturer plans his/her lessons calendars and books the remote labs for the interactive web sessions. The teacher can also plan experimental home works to be assigned to virtual groups of students. Thus the teacher needs to reserve a set of remote lab equipments, according with their availability or inform the equipment manager that virtual classes will reserve the remote equipment for their homework. The teacher is supported by an LMS, so the course schedule is updated in the system and a message is sent to the class participants for acknowledgement. On schedule the teacher masters the interactive webinar, describes the lab equipment (structure, components, guidelines of use, …), remotely interacts with its controls and comments the feedback both from the lab equipments and from the virtual classroom. Then the teacher shares the use of the lab equipment sequentially with one or two students, so they can reproduce the experiment shown, and the lecturer can assess the efficacy of the lesson.

At the end of the interactive session, the teacher assigns experimental home works to small working groups (2 to 5 students), who can independently book lab time-slots to carry out their activity.

On schedule the student joins his virtual group in the RCL. During the session they can interact in turn with the lab equipment, see and hear each other to discuss about the work and save the output of the assignment for further evaluations.

The teacher evaluates the homework and publishes the results on a virtual white board.

The whole scenario described above is viable if lab equipment manager publishes the calendar of its availability, saves the booking and the information about who has reserved what, in order to appropriately manage the access to the virtual equipment.

IV. EXTENDING MOODLE WITH MICRONET: AN EXPERIENCE

For our integration experience we have used Moodle and MicroNet. Moodle is a very popular LMS, rich of features, documentation and easily extensible. MicroNet is a collaborative, web-enabled Electron Microscope that can be remotely operated by small groups of 2 to 20 users. MicroNet is a complex piece of software, its complete integration with an LMS (and Moodle in particular) is not straightforward, so we decided to proceed step by step, i.e. component by component. We have mapped the main functional components of MicroNet, with the respective of iLab architecture [23]:

1) *the Interactive Lab Server* (ILS), in charge of permit the remote control, via Web, of a given lab equipment;
2) the *Interactive Service Broker* (ISB), that is the service for Authentication, Authorization, Administration and Ticketing;
3) the *Scheduling Server* (SS), which controls blocks of time allocated by a lab owner (Lab Side SS), and scheduling in a remote domain of lab users (User Side SS);
4) the *Experiment Storage Server* (ESS), which stores Experiment Records;
5) a further MicroNet component is the *Collaboration Server* (CS), in charge of the audio/video streams management during the CRL session. This component comes not from the iLab guidelines, but it is essential to enable the synchronous collaboration features of MicroNet.

Even if the functional components almost coincide, it must be noted that MicroNet technical implementation is different from the iLab one. Moreover, MicroNet only implements a subset of ISB, SS and ESS functionalities. This is the reason why we have started the integration from the ILS and CS components.

The functional structure of MicroNet's ILS, schematically presented in fig. 1, shows how the lab equipment (the Electron Microscope controlled by its SmartSEM software module) is enabled to remote web control.

In a few words, the keyboard & mouse controlling the microscope are virtualized by an "input redirector" and filtered by a "user authentication" service and by an "equipment safety" filter to block all unauthorized or unsafe (for the microscope) commands. Then the microscope's display is grabbed, encoded and transmitted in real time (as an mpeg4 video stream, with some acceptable latency) to the remote clients' web browsers. The microscope's control is permanently assigned to a tutor, who can share it with the students (one at a time) during the remote session.

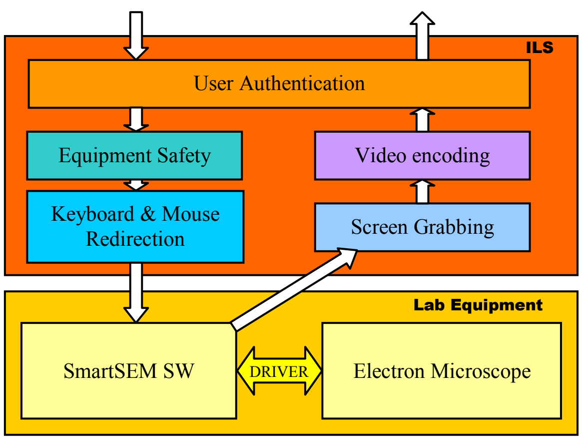

Figure 1. ILS functional architecture in MicroNet

A. *Integration approach*

From the technical point of view, Moodle is a Web application based on PHP and MySql. New functionalities can be added to Moodle by means of plug-ins, so we have rebuilt our ILS and CS components in order to be plugins compliant with Moodle. The ILS is essentially a server-side application, running on the lab server, so it has only required writing again its user interface and the driver controlling the client mouse and keyboard. The CS component, based on Macromedia Flash, has been easy to integrate, because Flash is well supported by Moodle. A minor redesign of the MicroNet user interface was also needed to adapt it to Moodle look & feel.

Figure 2 shows a screenshot of the Moodle-enabled version of MicroNet during an experiment session where a teacher is lecturing a group of ten students about the microscopic superficial structure of a metallic grid. The "Tools panel" contains four video panels (the teacher, a student and two ambient cameras to show what happens in the lab room) and the last two pictures acquired by the microscope. The Equipment Server's remote desktop (i.e. the *SmartSEM* software) is in the "Main panel", while the "Virtual Classroom" panel is the multi-videoconference among the session participants.

In terms of learning scenario, our main goal has been to permit to a Moodle class of 20 undergraduate engineer to participate to 4 Collaborative Remote-Lab sessions (one hour per session) on electron microscopy, in November 2009. The sessions were organized like interactive webinars, i.e. like a multi-videoconference where students could ear and see the teacher, and could remotely interact (one at a time) with the electron microscope by means of their web browsers.

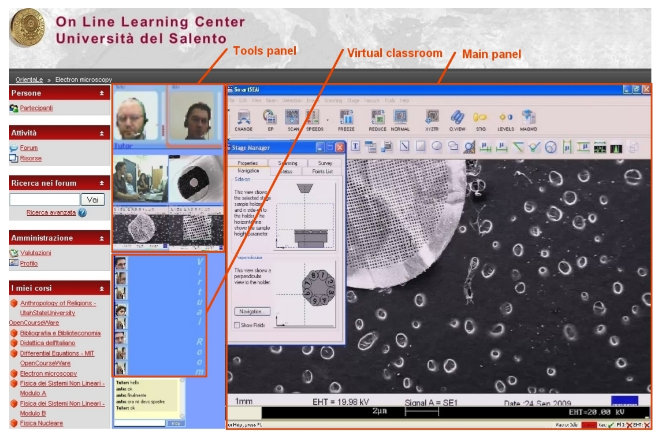

Figure 2. A screenshot of MicroNet in Moodle

B. *Results*

As previously stated, in this project we decided to disregard all the functionalities supported by the ISB, SS and ESS components, in order to focus our attention on ILS and CS. Two non-trivial integration problems emerged during the project. In the specific they are concerned with :

- The adoption of a single sign-on technique to authenticate and authorize Moodle users to interact with the lab equipment and to reserve its available time-slots;
- The exchange messages between the LMS and the CRL runtime environment, in order to perform the tasks made in the LMS with effects in the CRL (like a lab reservation) and vice-versa.

From the user point of view, the feedback was positive: the students rated the interface design intuitive, and easy to understand and operate. For the evaluation, after a microscope collaborative session of one hour (more or less), a teammate commented that the use of multivideo conference has appeared very valuable for design of new types of learning objects.

Moreover students stated that mixing collaboration tools, remote equipment controls and ambient video cameras was an effective approach to simulate the hand-on laboratory experience. Interestingly, and a little surprising for us, four users did not figure out by themselves that they were able to operate a real microscope and hence they were very skeptical whether the average user would be able to use the system.

V. CONCLUSIONS AND FUTURE WORKS

In the paper we presented the integration between Moodle and MicroNet, a platform for remotely control an electron microscope in a collaborative Web space. The integration project highlighted a number of problems, both technical and related to the learning scenario. Anyway the test in a laboratory class has highlighted that the adoption of the synchronous collaboration approach is promising. From the technical point of view, Micronet is evolving into a service oriented architecture able to connect several remote equipments and several virtual classes in a virtual workbench over the Web.

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