Teacher Training Plan for Engineering Online Laboratories Composition

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***Abstract*—Laboratory practices are a very important component in the training of engineers. Deficiencies in the training of engineering students generate deficiencies in the quality of graduates, these deficiencies are generated because higher education institutions do not have the infrastructure required to carry out student training processes, common reasons are: lack of budget for acquire the equipment, lack of space for the deployment of the equipment, high costs associated with maintenance and operation, etc.**

LACCEI in conjunction with the OAS and the company Lab in a Window developed a strategy to facilitate collaboration in Latin America and the Caribbean on the subject of online laboratories. As a result of this collaboration, an international network has been established for low-cost access and exchange of access to laboratory infrastructures that are adapted for access and control through the Internet. This initiative includes free access to LACCEI members to an online platform that offers access to online laboratories (virtual remotes and hybrids), these members can also share laboratory experiments in exchange for receiving access to other experiments that other participating institutions offer in the system.

This work presents a training plan for teachers of Engineering courses on how to compose online laboratories using Smart Laboratory Learning Objects (SLLO) created by a composer. In this case we specifically use the composer module of the SARL system.

***Index Terms*—Composer, Online Laboratories, SARL System, STEM, Training, Teachers.**

I. Introduction

The use of laboratories in higher education is a key factor in the acquisition of knowledge for most of the careers. In special, STEM education uses laboratory activities to understand specific concepts and enhance the practical skill that are important in the STEM field.

During the last 10 years, the online and blended education has increased significantly [1]. Online courses give to people the possibility to access education, without the need of move or to commute long distances to attend the classes. Blended education combines the best of both world: flexibility from online education and the interaction and communication between instructors and learners from the face-to-face education.

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2020.1.1.672
ISBN: 978-958-52071-4-1 ISSN: 2414-6390

During the 2020 pandemic, the demand for online courses and online curriculum has increased [2]. The requirement of practice social distancing, combined with the need to start a "new normality" that includes continuing education, face a challenge to universities and higher education institutions in order to provide quality education and hands-on experiences. Additionally, the economic impact of the pandemic has affected the educational institution that need to find new alternatives to offer practical experiences.

Online laboratories are a solution for institutions that offer online or blended educational programs and want to offer hands-on training to their students, and for institutions that do not have the infrastructure to set up some specific experiments. They are defined as an alternative to provide remote access through internet connection to real equipment or virtual experiments located in another place. The use of online laboratories can reduce costs in terms of space, equipment, maintenance, personnel, among others.

The rest of the paper is organized as follows: Section II presents a background on Online Laboratories for Engineering. Section III presents a brief description on the Smart Adaptive Remote Laboratories (SARL) Platform. Section IV describes the training plan for teachers in the area of engineering. Finally, Section VI states the conclusions of the paper.

II. Online Laboratories for Engineering

Laboratory courses in engineering education use several configurations such as physical laboratories, online laboratories, or a hybrid combination of physical and online laboratories.

During the last 10 years more online laboratories have been used to accomplish the practical requirement in education, using remote and virtual laboratories. The difference between remote and virtual laboratories is that a remote laboratory uses real physical equipment connected to a network that can be controlled remotely while virtual laboratories use simulators to mimic the behavior of real phenomena [3]. One important advantage on the use of online laboratories is the possibility of be used for one user or for many users simultaneously.

For blended education, the hybrid configuration has been widely used. In this configuration, physical and/or online laboratories are combined, then the users work on equipment

in a physical facility but also simulate some processes using virtual laboratories available externally.

Remote laboratories play an important role in academic areas like physics, chemistry, biology, medicine, and engineering. To accomplish the needed quality in higher education, the remote laboratories providers need to take in account the role of the users and how they use the services, and the necessity of integration and interoperability of these services with educational platforms. To comply with the requirements of interoperabily and integration, IEEE Education Society formed the IEEE-SA P1876 Working Group on Networked Smart Learning Objects for Online Laboratories to develop the standard that defines the architectures and implementation processes. The IEEE 1876 standard was approved in March 2019.

The current panorama of implementations of online laboratories can be described from different points of view: university, collaboration, and industry projects [7].

A. University Projects

First, implementations of online laboratories coming from university projects. These are some of the most representative university projects that were or have been active during the last two decades [7]:

- iLab project from Massachusetts Institute of technology (MIT) developed in United States
- the Virtual Instruments Systems In Reality (VISIR) developed at Blekinge Institute of Technology in Sweden (BTH)
- Weblab-Deusto from University of Deusto in Bilbao Spain, and the National Distance University (UNED) also in Spain
- Online Experimentation from Faculdade de Engenharia da Universidade do Porto (FEUP) in Portugal
- c-MOOLS from TELUQ University in Quebec Canada, Internet School Experimental System (ISES) from Charles University Prague in Czech Republic
- e-lab Instituto Superior Técnico (IST) in Portugal
- the Remotely Controlled Laboratories (RCL) from Universitat der Bundeswehr Munchen (UniBw M) in Germany
- Remote Labs Learning Environment (RELLE) at Universidade Federal de Santa Catarina (UFSC) in Brazil
- eLab / TeleLab projects from the Monterrey Institute of Technology (ITESM) in Mexico
- the Remote Farm from Berlin Institute of Technology in Germany

B. Collaboration Projects

Second, collaboration projects developed between two or more organizations, such as universities, government institutions or international organizations. Collaboration projects include [7]:

- UniLabs from UNED in Spain
- Library of Labs (LiLa)
- the Global Online Laboratory Consortium (GOLC)
- LabShare
- VISIR+
- Go-Lab
- Next-Lab
- Forging Online Education through FIRE (FORGE)
- the Network of Remote Laboratories (NeReLa)
- the Industrial Cooperation and Creative Engineering Education (iCo-op)
- Virtual Labs India (V labs)
- Modernizing Undergraduate Renewable Energy Education (MUREE)
- Platform Integration of Laboratories based on the Architecture of VISIR (PILAR)
- Micro Electronics Cloud Alliance (MECA)
- Electronic and Optic e-Learning for Embedded Systems (EOLES)
- Training in Automation Technologies for Ukraine (TATU)
- the North American Network of Science Labs Online (NANSLO)
- REMLABNET
- e-Lab Renata
- The Binational Laboratory for the Smart Management of Energetic Sustainability and the Technological Formation
- RedCLARA

C. Industry Projects

Finally, companies that offer services of online laboratories. Some of the most representative industry providers of online laboratory services are [7]:

- LabsLand
- Labster
- PhET
- HHMI BioInteractive

III. Smart Adaptive Remote Laboratories (SARL) System

A. Definition of SARL

The Smart Adaptive Remote Laboratory (SARL) was defined in the work of [7]. It provides to users experiences of the laboratory experiments according with their role. The user information is stored in a Virtual Learning Environment (VLE) along with educational content and the remote laboratories with the adapted interface. One laboratory experiment platform can be used for different laboratory assignments, topics, and courses.

The system can provide the user an individualized experience, after processing user information, such us experiences, previous knowledge, current acquired knowledge, and performance during the course. In this way, students from the same course, will have access to different activities that, in some cases, can use the same laboratory experiments exhibiting different levels of complexity in their interactions and requiring different levels of knowledge for its operation.

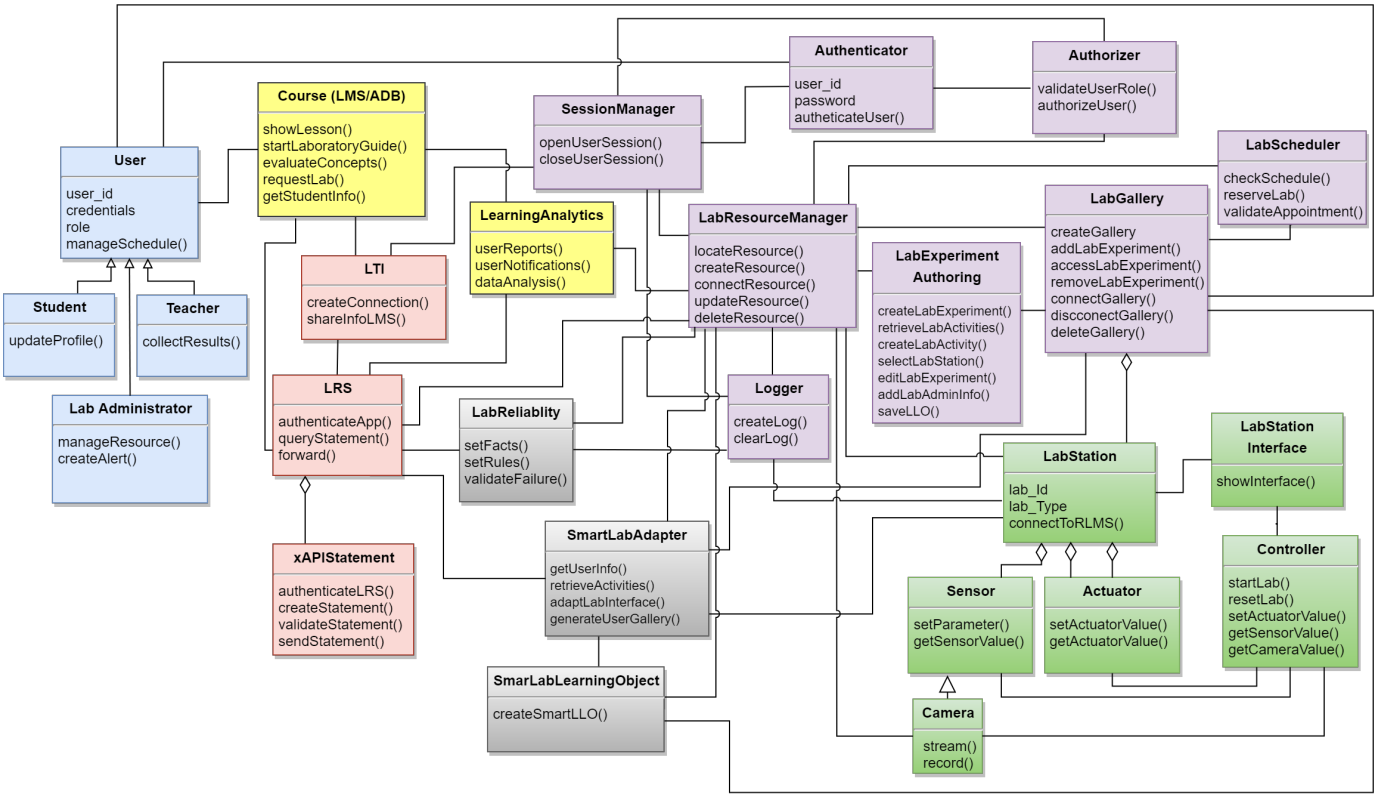

Fig. 1. Smart Adaptive Remote Laboratories (SARL) high level UML Classes Diagram [7]

B. SARL Architecture

Figure 1 presents the UML class diagram of the SARL architecture proposed in [7].

The architecture supports the adaptability of online laboratory graphic user interfaces GUI and activities according to the students' knowledge and previous results, reported by the VLE and the Remote Laboratory management System (RLMS).

The RLMS has four basic modules: user manager, scheduler, resources manager and the smart adapter. The scheduler gives teachers the ability to reserve the experiments in windows of time for groups of students.

The VLE system collects the information about users and their roles, and it shares this information with the RLMS system. This integration is possible through the use of standard technologies such as Learning Tools Interoperability (LTI) or through the implementation of web services.

The LTI module provides session information to the RLMS session manager and allows the correct user laboratory interface visualization inside the VLE.

The experience API (xAPI) module is in charge of the collection of the information about the user interaction with the system and to report it to the Learning Analytics module.

The Reliability Support module detects failures. These data are reported to the laboratory manager together with possible causes and solutions.

The Smart Adapter module or Smart composer retrieves the laboratory activities and assessment content from the VLE and connect them with one or more Online Laboratory Experiment to create SLLOs.

C. SLLO definition

The Smart Laboratory Learning Object (SLLO) was defined based on the definition of the Laboratory-based Learning Object (LLO) given by authors of [8] and the one proposed in the Lab4CE [9].

The SLLO was proposed as a package that can be deployed independently on a local computer or web server and provides access to laboratory experiences including one or more activities and access to local or remote resources [10], [11]. It can include different items such as class materials, examples, laboratory activities and the access to the hardware experiments needed for a specific laboratory.

In the SARL system, an Online Laboratory Experiments Composer was developed to provide a tool that can be used by teachers or laboratory administrators to create instances of laboratory experiments based on a set of available resources. The online laboratory experiments created in the composer can be saved and exported as a SLLO to be used on different VLEs.

The Online Laboratory Experiments Composer design module includes possibilities to put together elements that are used by students during the online laboratory experimentation sessions. Some examples of these elements are: Laboratory learning activities, virtual laboratories based on simulation,

access to real laboratory equipment, remote laboratories, assessments, and additional learning content such as documents, audio, videos, among others.

The online laboratory experiment can contain one or more activities attached to one or more online laboratory stations, as well as the possibility of attaching local or external digital resources.

Figure 2, presents the graphic user interface of the online laboratory experiment composer in SARL system [11].

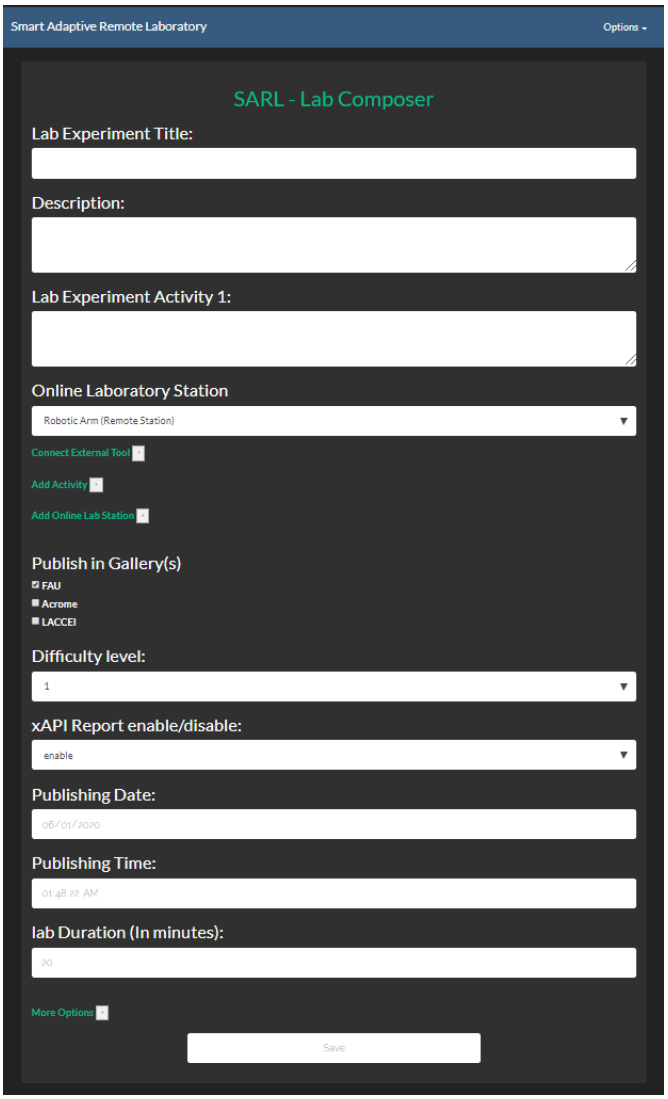

Fig. 2. OLMS - Online Laboratory Experiment Composer Graphic User Interface

IV. Training Plan for the Creation of Laboratory Experiments Based on the Remote Access to Existing Local or Remote Lab Stations

A. SLLO Creation

Part of the interopearability of the laboratory experiments relays on the use of a generic definition of an SLLO. These objects can be created or adapted by instructors following a procedure that is covered on the first module of the training.

Activities include:

- Identification and definition of the laboratory experiment and the SSLO metadata
- Definition of laboratory activities
- Connection to a remote or virtual lab station
- Addition of external tools to the activities
- Assessment mechanisms (auto-grading features)

The description of the learning outcomes for the SLLO creation and its evaluation is presented in table I.

TABLE I
Learning Outcomes for the SLLO Creation and its Evaluation

Learning Outcome	Evaluation
The participant is able to identify and define the metadata of the designed laboratory experiment	The metadata fields of the online laboratory experiment SLLO is clearly defined for the specific laboratory activities
The participant is able to define a set of activities related to the proposed online laboratory experiment SLLO	The Online laboratory experiment SLLO contains at least one activity to be performed by the students
The participant has the ability to connect to the online laboratory experiment SLLO, a remote or virtual laboratory station	The online laboratory experiment SLLO is functional and allows users to interact with the attached remote or virtual laboratory station
The participant has the ability to add external tools to the online laboratory experiment SLLO activities	The online laboratory experiment SLLO includes activities that can use the added external tools (text, images, video services, external simulators, etc)
The participant has the knowledge to add define levels of evaluation for the activities of the online laboratory experiment SLLO, taking advantage of the auto grading features provided by the Online Laboratory Management System OLMS	At least one of the activities of the online laboratory experiment SLLO is evaluated automatically by the system

B. SLLO Publication

After mastering the creation and adaptation of SLLOs, the instructor is ready to deploy these laboratory experiments, either on the laboratory gallery available on the SARL Online Learning Management System (OLMS) or linking the access

to some specific laboratory experiment or online laboratory experiments gallery directly in the LMS.

Activities include:

- Managing the visibility and availability properties of the laboratory experiment
- Publishing laboratory experiment in the SARL OLMS galleries
- Managing access permissions (Who can access the laboratory experiment) and access modality to the online laboratory (synchronous or asynchronous, based on the type of stations and external tools attached)

The module includes the development of a project that involves the creation of a real SLLO and its integration with the OLMS. For this, the trainee will count with laboratory stations test and external resources available in the SARL platform managed by Lab in a Window.

The description of the learning outcomes for the SLLO publication and its evaluation is presented in table II.

TABLE II
LEARNING OUTCOMES FOR THE SLLO PUBLICATION AND ITS EVALUATION

Learning Outcome	Evaluation
The participant is aware of the visibility properties (public, private), and availability properties (completed or draft) of the designed online laboratory experiment SLLO	The online laboratory experiment SLLO properties are configured according to the instructor definition
The participant is able to publish online laboratory experiments SLLOs in the SARL OLMS galleries	At least one online laboratory experiment SLLO is published in at least one SARL OLMS gallery
The participant has the ability to configure the access permissions and access modality of the online laboratory experiment SLLO	At least one online laboratory experiment SLLO has the access permissions with only users authorized to access, and the modality configured according to the type of laboratory stations attached to the online laboratory experiment SLLO

V. TRAINING PLAN FOR ADAPTATION OF A LOCAL LABORATORY STATION TO BE INTEGRATED TO AN OLMS

This module is intended to be done by technical staff within the laboratory facilities or by laboratory managers that can lead the adaptation of laboratory station process.

TABLE III
LEARNING OUTCOMES FOR THE LOCAL LABORATORY STATION ADAPTATION AND ITS EVALUATION

Learning Outcome	Evaluation
The participant is able to configure the hardware interfacing between the external controller external and the local laboratory station components	The participant completes the connection and configuration of the external controller with the local laboratory station components
The participant is able to configure the software to support communication of messages between the OLMS server, the external controller and the local laboratory station	The participant configure and test the software scripts in the OLMS server and in the external controller of the local laboratory station
The participant is able to make available the local laboratory station as a remote accessible laboratory station, including consideration of security	The participant deploy and test the functionalities of the new remote laboratory station from the OLMS server, validating security features provided by the OLMS

A. Topics for the training module

- Preparation of the interfacing controller
- Attaching the controller to the local laboratory experiment to enable sending commands and receive feedback to/from the laboratory station
- Attaching one or more cameras and configuring a video streaming service
- Attach scripts to the SARL API for specific functionalities that are not available on the current set of functions of SARL
- Preparing the network configuration to allow users access from external networks
- Check security aspects
- Testing and deployment of laboratory stations over SARL resources manager

The description of the learning outcomes for the local laboratory station adaptation and its evaluation is presented in table III.

B. Materials required for the training module

For the controller, a dedicated Single Board Computer (SBC) is recommended (Raspberry Pi3 or 4). The software requirements on this device are:

- Operating System (Raspbian based on Linux Debian)
- Application Server Apache 2
- PHP 7 or newer (Curl Extension is required)
- Video Streaming server Motion
- Python 3.7 or newer

For the cameras it is recommended to use IP cameras or USB cameras connected directly to the controller. The requirements on this device are:

- Main resolution 720 p
- Built in LED's to allow its usage when the local lab lights are off
- Wide angle range
- Motorized camera head and optical zoom (optional)

For networking, it is important to have at least one port open for external access for the communication and one port open for each of the video cameras. Technical personnel of the institutions should be involved in the configuration process in order to prevent security problems in the institutional network.

VI. Conclusions

The definition of the training plans for the module "creation of laboratory experiments based on the remote access to existing local or remote lab stations" and for the module "adaptation of a local laboratory station to be integrated to an OLMS", provide a general training structure with clear and measurable learning outcomes.

The "adaptation of a local laboratory station to be integrated to an OLMS" module, additionally, provides a basic knowledge to laboratory managers, required to enable their local laboratory stations as remote accessible online laboratory stations.

The two proposed modules are intended to be provided to laboratory classes instructors and laboratory managers that are interested in to offer online laboratory experiences.

Theses modules are planned to be offered initially to the interested population of instructors and laboratory managers from the Latin American and Caribbean Consortium of Engineering Institutions - LACCEI member institutions.

This project is part of the initiative for the development of a hemispheric infrastructure for the support of Learning Engineering, that initially will provide a platform for the management and sharing of online laboratories developed in the engineering field.

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