Massive Open Online Labs (MOOLs): An Innovative Solution to Achieving SDGs in the Global South

Fariba Moghaddam∗, Aldo Vaccari∗, Thomas Moniquet∗, Christophe Salzmann†, Yves Piguet†, Samer Saab‡, Rayana Jaafar‡, Amir Abolfazl Suratgar¶, Qobad Shafiee‖, Nomaou Dan Lamso∗∗, Hassane Alzouma Mayaki∗∗, Hassan Ali Barkad§, Hamadou Saliah Hassane††, and Denis Gillet†

∗University of Applied Sciences and Arts Western Switzerland, Sion, Switzerland
Email: fariba.moghaddam@hevs.ch, aldo.vaccari@hevs.ch, thomas.moniquet@hevs.ch
†Ecole polytechnique fédérale de Lausanne (EPFL), School of Engineering, Lausanne, Switzerland
Email: firstname.lastname@epfl.ch
‡Lebanese American University, Byblos, Lebanon
Email: ssaab@lau.edu.lb, rayana.jaafar@lau.edu.lb
¶Amirkabir University of Technology, Tehran, Iran
Email: a-suratgar@aut.ac.ir
‖University of Kurdistan, Department of Electrical Engineering, Sanandaj, Iran
Email: q.shafiee@uok.ac.ir
∗∗Université de Abdou Moumouni, Niamey, Niger
Email: danlamso.nomaou@auf.org, hassane.alzouma-mayaki@auf.org
§Université de Djibouti, Institut Universitaire Technologique Industrielle, Djibouti
Email: hassan_ali_barkad@univ.edu.dj
†† TÉLUQ University, Montréal, Canada
Email: hamadou.saliah-hassane@teluq.ca

Abstract - **In engineering education, laboratories represent an important academic resource as they provide practical training in addition to the fundamental theories. However, the acquisition of new machinery and the maintenance of the equipment imply a large investment that only a limited number of universities can afford. This paper represents innovative online education activities through a collaborative widespread network with the global south countries, deploying remote laboratories in electrical, mechanical and control engineering at a large scale within MOOC infrastructures.**

Keywords—Massive Open Online Labs (MOOLs), MOOC infrastructures, Smart devices, E-learning, Remote laboratories, Digital learning platforms, Authoring, Open Educational Resources, Learning analytics.

I. INTRODUCTION

The Massive Open Online Laboratories (MOOL) initiative is a collaborative project with the aim of sharing the Swiss expertise and infrastructures available at EPFL (Swiss Federal Institute of Technology in Lausanne) and HES-SO (University of Applied Sciences and Arts Western Switzerland) in digital education, with several institutions from the global south: Iran, Niger, Lebanon and Djibouti.

The rapid Internet development in the last decades has provided new possibilities and challenges for designing and deploying distance and collaborative learning systems. Web-based online experimentation turns to be a key feature in deploying digital education solutions in engineering education. It offers a tremendous opportunity to add flexibility in traditional curricula by providing students with versatile access to the learning material from both a time and location perspective. The experimental web-based training is highly beneficial for engineering schools in southern countries where scientific infrastructures are scarce, but where connections to internet are available. It enables remote control and monitoring of laboratory equipment, allowing students in engineering disciplines to perform experiments in real time, from anywhere and at any time.

The five goals of the project are:

- Establishing a strong north-south institutional cooperation for enhanced joint education and research activities as well as technology transfer, within the framework of the UN Sustainable Development Goals,
- Developing and implementing innovative and collaborative activities through an open, sustainable and widespread remote laboratories platform within digital technologies, e-learning environments and MOOC infrastructures,
- Enhancing pedagogical and student-centred learning and teaching methodologies through remote experimental activities,
- Reducing costs of laboratories in higher education by sharing the available infrastructures, resources and equipment of Swiss institutions for a large-scale use in engineering education.
- Promoting the exploitation of the European infrastructures for inquiry learning with online labs developed in the FP7 and H2020 frameworks and including a repository (golabz.eu) and a platform for the creation of open educational resources integrating online labs (graasp.eu).

II. Sustainable Development Goals

The project tackles the 5 following Sustainable Development Goals:

SDG 4 – Quality education: The project promotes online learning opportunities to improve quality education in southern countries. It contributes to promote STEM (Science, Technology, Engineering, and Mathematics) practices as well as ICT skills among young people.

SDG 5 – Gender equality: The project proposes equal training and educational opportunities to engage women in science and technology. Accordingly, we have chosen countries like Iran, Djibouti, Niger and Lebanon where gender inequality is one of the main issues.

SDG 9 – Industry, innovation and infrastructure: The project facilitates the deployment of sustainable technological infrastructures in south countries through educational support and technological assistance. It increases the access to information and communication technologies to support economic development.

SDG 10 – Reduced inequalities: The project offers favorable access conditions to education facilities for young students in engineering schools of least developed and developing countries. It upgrades education services, affording remote infrastructures and equipment not available in south countries.

SDG 17 – Partnership for the goals: Through a collaborative network, the project promotes the development, transfer and dissemination of engineering education in southern countries. The main objective is to mobilize and share knowledge as well as technology and resources to support the sustainable development goals.

III. Infrastructure

The infrastructure to support Massive Open Online Laboratories relies on a modular, operational, secure, scalable and "plug and play" paradigms [1, 2, 3]. It is composed of the following requirements:

Smart Device: A Smart Device (SD) provides a set of well-defined interfaces (API) that enable communication between the remote lab and the client application. It exposes the physical equipment sensors and actuators through an API that ensures interoperability. In addition to remote access, the Smart Device manages all the internal logic such as local controller, security, safety, logging, etc. through a set of defined functionalities.

The Smart Device specifications enable a complete decoupling between the client and the server and offer as such the opportunity for the creation of a wealth of client applications. The server infrastructure can also easily be adapted or extended to other configurations.

The systems considered for remote experimentation are mainly mechatronic systems with moving parts and visually observable dynamical behaviors, such as servomechanisms and robots.

Web client application running in a browser: Web browsers are de-facto environment for client applications. Client applications written in JavaScript enable students to fully interact with smart devices. Thanks to the Smart Device API, different client applications can connect to different SD services through the API currently standardized in the framework of the IEEE P1876 working group. For example, some client applications (Fig. 1) can access only the real-time video streaming while other display an oscilloscope like graphic, the video stream and a control panel to specify the parameters and the controller structure.

MOOC Hosting environment: The client applications are integrated in a MOOC platform (Swiss MOOC (edX) EPFL, MOOC HES-SO, Graasp.eu, …). Embedding the client application as a LTI [4] container guarantees a complete client integration within the hosting environment. A complete integration permits for example single sign on and/or grades saving.

Communication protocol: WebSocket [5] are currently the most effective way of exchanging information between the client web application and the Smart Device server. The information is encoded as JSON [6] packets that follow the Smart Device specifications.

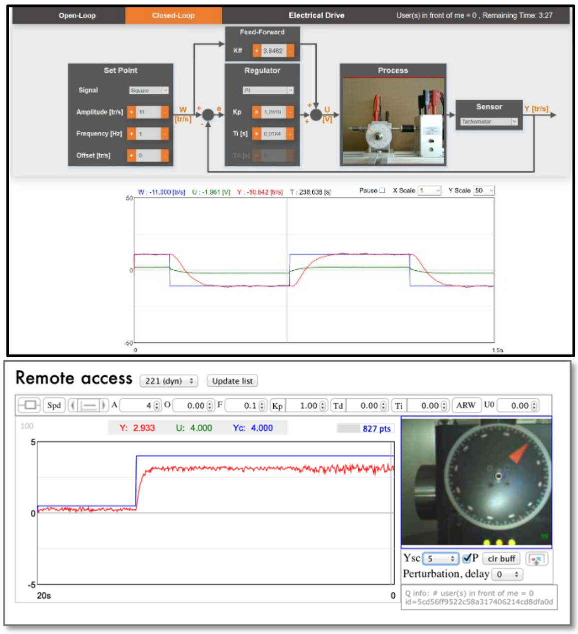

Fig. 1. Examples of Web client application.

Additional services: In order to have an interactive and easy to use platform, some other services (Fig. 2) such as students' activities, data processing, numerical simulation, data saving, e-journal and booking system can also be included into the system.

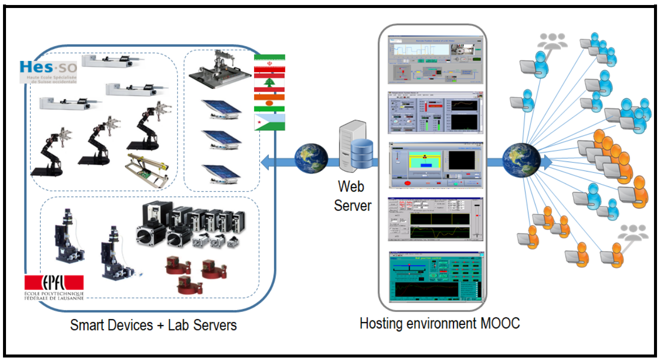

Fig. 2. Online remote laboratories infrastructure.

IV. The Remote Lab

Along with the existing pool of educational remote laboratories (labs) available at EPFL and at HES-SO, such as servomechanisms and robots, the project aims at offering a new pool of sustainable renewable energy installations operating under real weather conditions to be installed in the southern countries (4 devices per south partner).

The Swiss Bachelor students in electrical and mechanical engineering disciplines are supposed to use the photovoltaic panels installed in the south to do different real measurements and to test control algorithms (angle, temperature, PV voltage output , power,...) under warmer and more severe weather conditions than those typically observed in Switzerland.

The proposed system offers the ability to students to remotely conduct experiments with a real photovoltaic panel. The PV panel (Fig. 3) facing south is a moveable system actuated by a motorized structure allowing to adjust its tilt angle from 0° to 90°. A camera offers continuous live video streaming of the test site in addition to other remote measurements such as tilt angle, voltage, current, supply power and temperature. A solar charge controller and a battery complete the set of PV panels experimentation system.

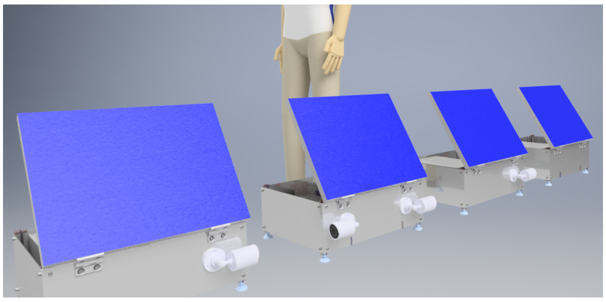

Fig. 3. Set of instrumented and moveable PV panels to be installed by each south partner.

V. SCENARIOS

From a pedagogical point of view, the project deals with the extensions of the Swiss e-Infrastructure for self-organized learning environments. Different learning scenarios and pedagogical contents split into theoretical, experimental and evaluation phases lead the student during the laboratory session. Real-time Interaction over the Internet should enable students to efficiently interact with physical distance equipment, as an efficient interaction provides them with the best possible feedback to minimize drawbacks inherent to the distance, with sufficient information to reproduce the state of the distant equipment and its operational conditions. Based on pedagogical contents, students are able to get orientation on their own, as well as to determine and elaborate adequate learning methods for new competences and skills.

The proposed e-learning setup is implemented in MOOC platform and is actually fully dedicated to hands-on activities. The learning scenario of each session is split into short videos describing how to use the various tools (experiment description, theoretical development, control panels, …) , a set of offline exercises and a set of numerical questions (quiz form) to validate user's finding and to evaluate user's understanding.

For example, a scenario where the user has to design a controller for a given process could have the following sequence:

1. Watch the introduction video, which describes the different part of the smart device and provides a theoretical recall.
2. Perform a step response acquisition on the real system and save the measurements. During this step a remote connection to the smart device is established.
3. Process the measurements to identify the transfer function of the system.
4. Enter the transfer function parameter in the corresponding MOOC module for self-validation.
5. Use the identified transfer function to design a controller following predefined specifications. Enter the controller parameters for self-validation.
6. Test and validate the designed controller on the real system, through various experimentations.
7. Add a disturbance on the real system, and test if the designed controller is robust to such a disturbance. For example, an additional load or a delay can be added to the system.
8. Answer additional comprehension questions.
9. Upload the lab report.

In the above scenario, the remote lab is only accessed in steps 2) and 6) and 7). A specific experimentation time is defined for each task to be performed. This parameter, defined by the MOOC authors, facilitates a tight time control for each experiment. The other steps do not require timing since the web tools used for analysis and/or simulation run on the client browser without live connection to the lab server.

A. Scenario in Tehran-Iran

The new solar package system will be installed in the Industrial and Optimal Control Research Laboratory (IOCRL) at Electrical Engineering Department of Amirkabir University of Technology. Educational and research activities will be first modelling and identification of the PV panels. Next step will be optimal controller design for obtaining MPP and distributed optimization [4]. The students will also compare the efficiency of the moveable solar package system of the project MOOLs with the existing fixed PV in IOCRL Laboratory.

B. Scenario in Kurdistan-Iran

The provided devices will be implemented in the Smart/Micro Grids Research Center (SMGRC) at University of Kurdistan. We plan to use the PV panels for different types of testing and validation capabilities, not only for education but also for research. Bachelor students (from Electrical or Mechanical Engineering disciplines) who take the control engineering courses, e.g., Linear Control Systems, are supposed to use the provided setups for getting familiar with the concept of PV systems. The students will study different aspects of modeling, stability analysis and control design. They will be asked to design experiments studying effects of panel angle, solar irradiance and load resistance on the output power, as well as efficiency of the panels. In addition, different control techniques and new ideas will be studied by the graduate students for research purposes.

C. Scenario in Lebanon

The provided PV Panels are to be installed in the Control Systems Laboratory in the Engineering Laboratory and Research Center (ELRC) at the Lebanese American University, Byblos Campus. The remotely controlled devices will be integrated in the Control Systems Laboratory course in order to expose the students to the process of controlling additional physical systems. The students will also be able to mathematically model the PV panels on MATLAB and compare their numerical simulations to their experimental results while employing different classical controllers. In addition, the devices will be made available for students taking the Senior Capstone Design Project course with the ability to control the PV panels using Simulink Real Time using more sophisticated designs.

D. Scenario in Djibouti

The PV panels will be installed at the new campus of Balbala and will be integrated in the laboratory activities in electrical and control engineering for the students of the Institute of technology and the faculty of engineering.

We will also study the impact of tropical desert maritime climate on the performance of the PV panels, indeed Djibouti is known for its extreme weather conditions (temperatures range from 35°C to 45°C in summer with dry winds and dusts).

E. Scenario in Niger

The Niger team will expand with the participation of other colleagues from universities and schools located in Niger. For sustainability, the dynamics fit into that of a participative research action and training to which we deeply believe.

This project will allow us to express our needs and benefit from internationally recognized Swiss expertise in the standard based design and implementation of remote laboratories [7]. We will also contribute with our own know-how [8]. The devices designed in this project will be installed in our CNF, the Francophone Digital Campus (Campus numérique francophone™) at Université Abdou Moumouni. The CNF already offers access to Internet services and online interoperable digital resource repositories for the scientific community of the universities in the country. The remotely accessible educational resources designed and deployed in the framework of this project will be integrated and exploited in hybrid mode [9], in the hands-on laboratory activities of the three courses: Applied Technology, Computer Aided Analysis and Design and the Pumping and Optimized Irrigation course under development for the Faculty of Agronomy. Each one of these courses contains Control Education hands-on laboratory work. Some scenarios will be also developed for interdisciplinary and multidisciplinary project based flipped classroom online learning and teaching activities.

VI. BOOKING SYSTEM

The booking system that will be exploited in the project has a unique user interface to manage all the remote labs, across several sites. To book a remote lab, one needs to be authenticated, within the booking system. If the remote experiment is available, for the given time in the calendar, a unique booking key is generated and sent to the user, by mail.

There are three types of bookers: a) The lab Owners of each site can decide when and how many of their remote labs are available. Therefore, they can book time slots in advance, for example, once per semester. If necessary, they have the right to correct the booking user errors. b) The teachers have the right to do booking for a group of students. They can book more than one remote lab in a time slot. c) The students can only book one remote lab in a time slot (individual use).

If two users want to book the same resource at the same time, FIFO policy will apply. Booking makes sense if the user is in controller mode. The users in observer mode do not need to book the remote labs through MOOC. For each remote lab type, as all the experiments are identical, for example 10 identical servomechanisms at HES-SO, it is not possible to book a specified one.

VII. AUTHORING AND LEARNING PLATFORM

The graasp.eu digital education platform [10] has been developed with the support of the European Commission and Swiss public funds to support personal, collaborative and inquiry learning. It is now freely open to any educational institutions or nonprofit organizations promoting active learning and knowledge sharing. It can be uses together with the golabz.eu repository for STEM education with online labs.

In addition to enable higher education students or tutors to create shared spaces aiming at carrying out personal or collaborative activities, as well as to aggregate personal or cloud resources, Web links or discussions, graasp.eu enables teachers to create and use with their students open educational learning resources (OERs) [11]. These OERs are graasp learning spaces that can be structured with subspaces integrating multimedia content, cloud resources, Web links, online labs, supporting apps or discussion threads necessary to support the various phases of dedicated learning sessions. The learning spaces are LTI compatible modules and can be integrated in Learning Management Systems (LMS) in addition of being simply used directly in graasp by students which can access them through a secret URL without registration. This anonymous nickname-only access scheme is part of the privacy-by-design features of the platform.

The original design of the graasp platform enables the creation and the use of MOOC in an agile way without the need to rely on complex legacy platforms like coursera or EdX and without engaging in complex negotiations with service providers and platform managers [12]. In a few clicks, any graasp user can create a MOOC structure, drag-and-drop YouTube videos, integrate remote lab client apps, add instructions, quiz tools or discussions threads (Fig. 4).

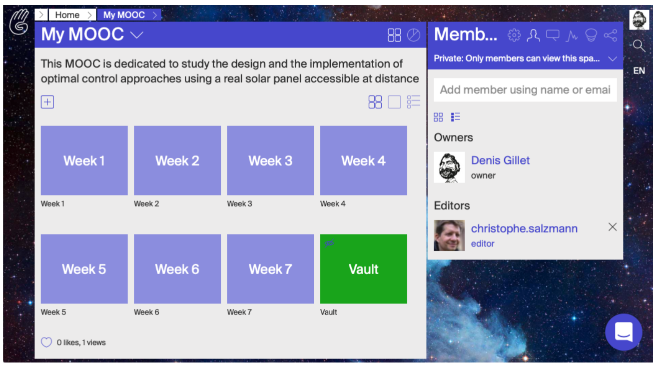

Fig. 4. A MOOC created in graasp with subspaces corresponding to weekly activities.

Once populated by the teacher and shared as a single Web page using the sharing tab, the MOOC be used by the students to carry out their learning activities. Figure 5 shows the content of one week with an introductory video capsule.

Activity tracking can be enabled in any MOOC module to offer additional learning analytics tools encouraging students to reflect on their learning activities and teachers to reflect on the design and the orchestration of these activities.

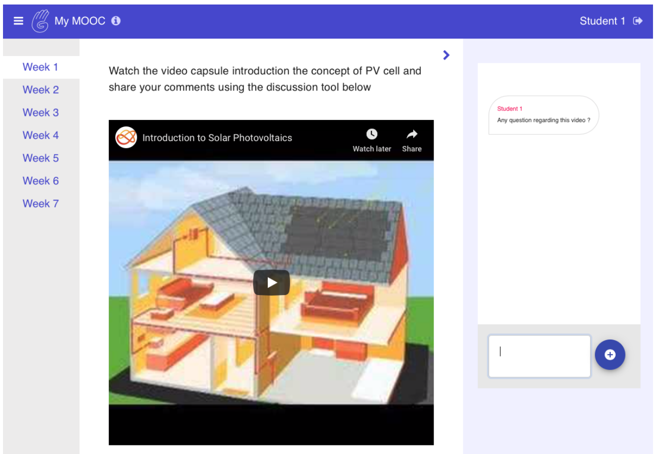

Fig. 5. The single Web page view accessible by the students corresponding to the first week of the MOOC prepared by the teacher and showing an introductory video capsule from YouTube.

Contrary to LMS, graasp is keeping the users and their content as long as desired. Hence, the platform can be exploited as an integrated ePortfolio system. Teachers can also export their content as zip archives and students their learning outcome as eBooks if they wish to keep their resources outside the platform [13].

VIII. CONCLUDING REMARKS

The design, development and construction of the different remote devices and their control systems have been currently done, altogether with the communication protocols which have been successfully experimented. The remote control and test of PV panels in south countries and the evaluation and optimization of the different learning scenarios by students and teachers are expected by the end of 2019.

Other activities like software tools to implement additional services such as data processing, numerical simulation and data saving and monitoring are also planned. We also expect to connect our online laboratories with different analytic tools to get data and information from the learning process during the interaction of the students with the remote lab.

A mediating tool to support and share knowledge acquisition and reinforcement in a sustainable collaborative way is also intended to be developed. The tool integrated into the MOOLs environment will be designed as a shared workspace that supplies different metrics for sharing, monitoring and evaluating the collaborative learning process in flexible hands-on activities.

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