LabsLand: A sharing economy platform to promote educational remote laboratories maintainability, sustainability and adoption

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***Abstract*—A remote laboratory is a software and hardware tool that enables students to access real equipment located somewhere else through the Internet. The laboratories are typically deployed in universities or research centers. A key factor of remote laboratories is that once they are available through the Internet their usage can be scaled up and used by students of other institutions. Thus, two or more institutions can share different equipment to reduce costs. Furthermore, this enables a sharing economy where multiple providers provide access to their laboratories to each other, freely or not. However, while the number of remote laboratory initiatives is high, the overall impact of these laboratories is fairly limited beyond the scope of the host institution or the scope (and duration) of projects in which the host institution is involved. The focus of this contribution is to outline a novel initiative addressing this scaling problem. After over 10 years working on the area our research group has started a spin-off focused on this topic, called LabsLand. A key factor of this spin-off is to provide a platform similar to other sharing economy marketplaces, aiming to provide features commonly ignored in the remote laboratories literature such as trust, accurate reliability or different pricing schemes for different scenarios.**

I. Introduction

An Educational Remote Laboratory is a software and hardware solution that enables students to access real equipment located in their institution, as if they were in a hands-on-lab session, using an standard web-browser. The laboratories are typically deployed in universities or research centers.

A key factor of remote laboratories is that once they are available through the Internet their usage can be scaled up and used by students of other institutions. Thus, two or more institutions can share different equipment to reduce costs by requiring less duplicated equipment: it is typically only used in certain hours of the day and in certain days of the year. Furthermore, this empowers a sharing economy where multiple providers provide access to their laboratories to each other, freely or not.

In the literature there is a wide range of remote laboratories in many fields (e.g., robotics, electronics, physics, chemistry). Software frameworks have been developed to make the development of remote laboratories more affordable (e.g., Remote Laboratory Management Systems such as WebLab-Deusto[1] [1], iLab Shared Architecture[2] [2], RemLabNet[3] [3] or Labshare Sahara[4] [4]) and tools (e.g., gateway4labs[5] [5]) to provide integrations with educational tools (such as Moodle, Sakai or other LMS, both through ad hoc solutions and through standards such as IMS LTI) or repositories linking remote and virtual laboratories (such as Go-Lab[6] [6], [7], LiLa[8] or iLabCentral[7]).

However, while the number of remote laboratory initiatives is high, the overall impact of these laboratories is fairly limited beyond the scope of the host institution or the scope (and duration) of projects in which the host institution is involved. There are cases where the laboratories are regularly used by other institutions, but these are still exceptions and remote laboratories are not yet widely used. This is not the case for virtual laboratories (simulations), where the maintenance costs and work required once developed tend to be low.

In the literature there are studies that identify key elements for this problem: lack of a technical framework, pedagogic framework or proper strategy. Some business initiatives have been created focusing also on the sustainability (such as Labicom[8] [9] or RemoteLabs.in[9]), but also with a limited reported impact.

The focus of this contribution is to outline a novel ini-

[1]http://weblab.deusto.es
[2]http://ilab.mit.edu
[3]http://www.remlabnet.eu
[4]https://remotelabs.eng.uts.edu.au
[5]http://gateway4labs.readthedocs.org
[6]http://www.golabz.eu
[7]http://www.ilabcentral.org/
[8]http://labicom.net
[9]http://remotelabs.in

tiative addressing this scaling problem. After over 10 years working on the area our research group has started a spin-off, called LabsLand[10] focused on this topic. Aligned with the FIE2016 theme (The Crossroads of Engineering and Business), this contribution outlines the key component developed by this company: a portal that acts as a repository of remote laboratories supporting multiple providers (relying on existing interoperability efforts), but which provides a quality assurance mechanism (not available at this moment in any of the repositories found in the literature), and based on simple contracts (supporting both free sharing and paid sharing) that aims to provide reliability to the final users and sustainability for the laboratory providers.

The paper is structured as follows: Section II introduces the concepts of remote laboratory, remote laboratory management system and remote laboratory federation for explaining what are the current initiatives of sharing remote laboratories. Then, Section III briefly explores existing commercial solutions for sharing economy models, and key features detected on them. Section IV elaborates the discussion on why taking some of the key features present in commercially successful sharing economy platforms should be included for sharing remote laboratories too. Section V explains the platform being developed by LabsLand taking the key factors into account. Finally, Section VI describes the conclusions and the future work.

II. Current solutions for sharing remote laboratories

This section introduces the concepts of remote laboratories, Remote Laboratory Management Systems (RLMS), remote laboratory federations and portals for sharing remote laboratories.

A. Remote Laboratories

A remote laboratory is a software and hardware tool that allows students to remotely access real equipment located in the university. Users access this equipment as if they were in a traditional hands-on-lab session, but through the Internet. To show a clear example, Figure 1 shows a mobile low cost robot laboratory described in [10]. Students learn to program a Microchip PIC microcontroller, and they write the code at home, compile it with the proper tools, and then submit the binary file to a real robot through the Internet. Then, students can see how the robot performs with their program through the Internet (e.g., if it follows the black line according to the submitted program, etc.) in a real environment.

In this line, there are many examples and classifications in the literature [11], [12]. Indeed, remote laboratories were born nearly two decades ago [13], [14], [15], and since then they have been adopted in multiple fields: chemistry [16], [17], physics [18], [19], electronics [20], [21], robotics [22], [23] and even nuclear reactor [24].

B. Remote Laboratory Management Systems

Every remote laboratory manages at least a subset of the following features: authentication, authorization, scheduling users to ensure exclusive accesses -typically through a queue

[10]http://labsland.com

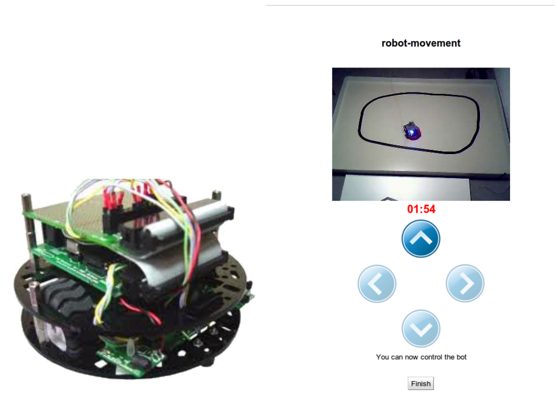

Fig. 1. Robot laboratory [10]. At the left, the mobile robot itself. At the right, the user interface once the program has been submitted.

or calendar-based booking-, user tracking and administration tools. These features are common to most remote laboratories, and are actually independent of the particular remote laboratory settings. For example, an authentication and queuing system is valid both for an electronics laboratory and for a chemistry laboratory.

For this reason, Remote Laboratory Management Systems (RLMSs) arose. These systems (e.g., MIT iLabs[11], WebLab-Deusto[12] or Labshare Sahara[13]) provide development toolkits for developing new remote laboratories, as well as management tools and common services (authentication, authorization, scheduling mechanisms). The key idea is that by adding a feature to a RLMS (e.g., supporting LDAP, a Learning Analytics panels [25] or similar cross-laboratory features), all the laboratories which are managed with that RLMS will support this feature automatically.

C. Federating Remote Laboratories

As previously stated in the introduction, a key factor of remote laboratories is that once the laboratory is available on the Internet, it can also be shared with other institutions.

To do this, there are three general approaches:

- Leave the laboratories completely open, so whoever wants to use them can use them. This may reduce the chances of providing proper Learning Analytics or supporting proper accountability mechanisms, in addition to avoiding priorities among students coming from different institutions, leading to a tradeoff between accessibility and advanced features [5].
- Share accounts between the different RLMS: if *University A* want to use laboratories of *University B*, then someone in *University A* will provide a list of usernames to *University B* and students will go to this institution using credentials in *University B*. Ideally, some federated authentication could be used to avoid providing credentials in different domains (such as Shibboleth, OAuth or similar), but it is not typically the case.

[11]http://ilab.mit.edu
[12]http://weblab.deusto.es
[13]http://github.com/saharalabs

- Federate laboratories: if a RLMS supports federation, then if installed in two different institutions (e.g., *University A* and *University B*), students of *University A* will go to the RLMS of *University A* and they will transparently use laboratories in *University B*, working in a institution-to-institution basis (so *University B* does not need to know the list of students of *University A* and simply rely on an existing agreement with that university).

From the items in this list, the most advanced mechanism is the federation of remote laboratories through proper protocols oriented to market-like situations. These federation protocols have been used for fostering interoperability between RLMS [1]. These interoperable bridges between different systems can be enhanced if properties such as transitivity or federated load balance are provided [26].

D. Remote Laboratory Portals

In the literature there are different portal solutions that provide listings of virtual and remote laboratories. In [27] 13 repositories are analyzed, out of which 6 were involving remote laboratories (the rest are virtual laboratories -simulations-), plus another one is presented (golabz). Most of these repositories provide a portal with more or less features, including: social features (e.g., rating resources, adding comments, tags), materials (users' materials, students' materials, teachers' materials) or supportive apps. In particular, the Go-Lab portal (golabz[14]) provides all these features, providing support for both remote and virtual laboratories, a pedagogic framework, tools for sharing and reusing pedagogic contents and tools for publishing results.

III. Sharing economy platforms

During the last decade, and especially during the last few years, there has been a rise in different online platforms that enable sharing the costs of some scarce resource among different consumers by renting them. Examples typically include, among others:

- ZipCar[15]: car rental platform that enables short intervals of times and focused on making the process especially easy for drivers, who can do the whole rental process from their smartphone. Cars are provided by ZipCar.
- Airbnb[16]: house/room rental platform, where two types of users are identified: hosts and guests. Hosts make their house or a room available through the platform but sometimes requesting an interview or contact with the potential guest. Guests have access to a large amount of rooms and houses.
- Blablacar[17]: car ride-sharing platform that enables drivers and passengers to organize rides. Drivers who are going to do a ride post in the platform when they are going to do it, how many available seats they have, and how much they would charge per passenger. This way, typically passengers get a cheaper ride and riders get the ride mostly paid.

There are many other examples, and important differences between the three examples mentioned: In ZipCar, customers use cars provided by the company, not by other customers, as it happens in the other two. Additionally, in Airbnb, the motivation for providers (hosts) is to raise some money while renting a spare room or house, while in Blablacar the target for providers (drivers) is not to have benefits but to reduce the cost of rides that they are going to do anyway.

While in this contribution we refer to these phenomenom as *sharing economy platforms* [28], [29] (its most popular term nowadays), this phenomenom is not new and has received different names in the literature. Osterwalder et al. [30] call *Multi-Sided platforms* to those business platforms that aim two types of users, where some are providers and other consumers, using the PSP/Xbox consoles as example (where gamers aim powerful consoles and game developers -paying royalties- aim a wide audience of gamers). The same authors in [31] indeed mention the Airbnb example in the category of *double-sided platforms*. Salim Ismail in [32] analyzes patterns of many of these businesses (and explaining how they have to deal with important problems such as trust) classifying them (with other types of companies) as *Exponential Organizations*. Robin Chase (Zipcar co-founder) in [33] refers to them as *Peers Inc.* to emphasyze the fact that there is a set of individuals (*Peers*) both providing and consuming a service or resource (and where the strenghts are indeed the localization, specialization and customization), as well as a company platform (*Inc.*) providing where there are industrial strenghts (that requires scale and resources). While some of these authors also use terms such as *sharing economy*, *peer-to-peer startups* or *peer-to-peer marketplaces*, [34] points out that the term *sharing economy* is not accurate since in most platforms nothing is shared more than among guests in a hotel and *access economy* would be more appropriate.

Regardless the term used, they all agree in that a key feature in all these platforms is delivering verifiable trust. Airbnb co-founder Joe Gebbia [35] points out trust as a key feature for Airbnb since both guests and hosts need to trust each other to run the service, explaining how the Airbnb reputation system does not change much with few opinions but after a threshold of around 10 (good) opinions, the chances of one trusting that person increase considerably. Indeed, trust is analyzed in studies [36] which compare the results of the reputation system of Airbnb with hotels opinions in TripAdvisor (where the average punctuation is lower than Airbnb), pointing out some potential reasons (from individual entrepreneurs offering rooms in Airbnb would be more selective with which guests to accept so as to avoid a bad opinion or resetting the page to a fresh property page to avoid having past bad opinions). In [37], the profile pictures in Airbnb are analyzed to verify how trustworthiness is affected. Furthermore, as reported in [38], Airbnb as of July 2013 dedicated 50 people of the 300 people involved in customer-service to trust and safety, but also other companies took similar approaches, such as Lyft conducting in-person driver screenings and criminal background checks. Also in blablacar trust is also critical, as explained in [32], where the co-founder of the company explains the

[14]http://www.golabz.eu
[15]http://www.zipcar.com
[16]https://www.airbnb.com
[17]http://blablacar.com

D.R.E.A.M.S. trust framework[18] as key for their business.

IV. Discussion

As mentioned in Section II-D *Remote laboratory portals*, some repositories (such as golabz) for virtual and remote laboratories do provide social features (e.g., rating resources, adding comments, tags), materials (users' materials, students' materials, teachers' materials), as well as supporting applications, a pedagogic framework or tutoring platforms [39].

However, none of the existing portals provides trust mechanisms other than user-based ratings, and typically those portals supporting user-based ratings do not have many ratings, and with few context about who is the person providing the rating, how much as used the tool, etc.

This might be a minor issue in certain environments, where trust on the tool is not so critical, such as where the tool is reliable (e.g., it is a simulation) and it is always freely available. However, in the field of remote laboratories, sustainability remains as an open problem [40]. An important advantage is that two institutions can share real laboratories, real equipment, reducing the costs if these costs are somehow shared. However, regardless the federation protocols built (see Section II-C), it is not possible to engage different institutions in using each others' laboratories if there is no reliable mechanism to trust the reliability of the laboratories and the ability of the host institution to fix the problems if they appear.

However, there is usually no way for the existing remote laboratory portals to know whether the laboratories are running or not, how often failures happen (e.g., what was the percentage of uptime during the last 9 months?) or how long does it usually take to the laboratory owners to fix it. The portals are additionally unable to track the usage of the tools from third parties (e.g., they are when it is about their own resources) and publicly display this information in a way useful for teachers (e.g., what laboratories are more popular in the repository?). Furthermore, the existing portals do not embrace the ability to manage the usage of the laboratories and manage potential payments.

We consider that this is a key factor for the not spread usage of remote laboratories among different institutions (as compared with their wide usage in the host institutions [41]). No RLMS and no portal provide the ability to manage payments properly (not necessarily by paying per access, but through fixed rates or virtual mechanisms where the more someone uses your labs, the more you can use labs of other providers), and even if they did, no portal has the ability to provide real data on how reliable and trustworthy a particular laboratory is. Without such information, the trust relation completely relies on direct relationship between the provider and the consumer (where the consumer must trust on the provider because they know each other or other reputation system).

With such a portal, and with the technologies, pedagogic frameworks and tools already demonstrated in the literature, we consider that it will be possible to engage different providers and different consumers to use remote laboratories. Only if this adoption happens, it will be possible to foresee a sustainable and maintainable model for a distributed network of remote laboratories.

For this reason, after over 10 years working on the field of remote laboratories under the WebLab-Deusto umbrella, we have launched a spin-off of this project, called LabsLand[19].

V. LabsLand portal

LabsLand is a spin-off of the WebLab-Deusto[20] research group. As part of WebLab-Deusto, the team has worked on:

- A set of remote laboratories, including physics, electronics or biology.
- An Open Source Remote Laboratory Management System called WebLab-Deusto[21] for the development of remote laboratories. This RLMS is used in a number of universities in different countries (Spain[22][23], Slovakia[24], Brazil[25], Serbia [42] or Georgia[26]).
- A federation model and protocol for sharing laboratories in a market-like decentralized environment [26].
- A set of tools for interoperability with other RLMS: both ad hoc [1], [43] and through a collaboratively developed and Open Source system called gateway4labs [5], [44].

Now as part of LabsLand, and on top of the experience and maintaining the tools mentioned above as Open Source, a spin-off has been created to deal with the pitfalls pointed in Section IV. The spin-off, in addition to explore business models around remote laboratories, provides a centralized portal (see 2) that will act as a technology-agnostic marketplace for remote laboratories consumers and providers. The portal does not rely only in own technologies (such as WebLab-Deusto), but also supports external providers. To this end, interoperability efforts have been placed in gateway4labs[27] to support external remote laboratory providers, including the iLab Shared Architecture, RemLabNet, UNR-FCEIA or repositories including remote laboratories such as ViSH.

The portal tries to guarantee trust from the very beginning, by regularly and automatically checking the existing resources to be able to provide trustworthy information to the teachers on which laboratories are reliable and how much (with several different types of automatic checks), and enforcing different policies on the remote laboratory providers to be clear on when the laboratory is going to be available. The portal will not penalize that a remote laboratory provider is not working 24/7: it will just require remote laboratory providers to define in which time ranges it should be available and penalize those not being online during the defined time. In addition to this, public opinions (only of those having used the platform) and

[18] http://www.betrustman.com/

[19] http://labsland.com

[20] http://weblab.deusto.es

[21] http://github.com/weblabdeusto

[22] http://weblab.ieec.uned.es

[23] http://weblab.deusto.es

[24] http://weblab.chtf.stuba.sk

[25] http://weblabduino.pucsp.br/weblab/

[26] http://weblab.bsu.ge/

[27] https://github.com/gateway4labs/

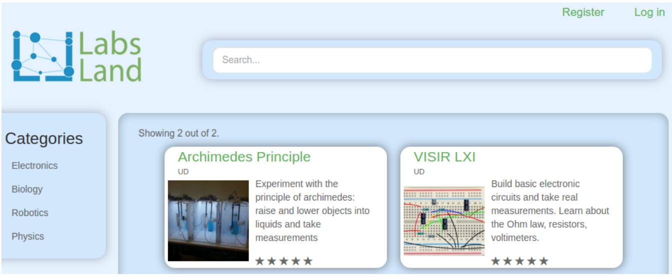

Fig. 2. LabsLand portal. It will be publicly available for the beginning of the course 2016-2017.

all the D.R.E.A.M.S. framework values are considered in its design.

However, LabsLand does not envision the usage of the portal as the only possible tool. In the future (after the first version), it will also provide support for standard protocols such as IMS LTI or its inclusion in OpenSocial. And agreements with existing repositories to publish the laboratories there will be encouraged, while some registration process by end users will be required in LabsLand.

VI. Conclusions

The daily usage of remote laboratories has been reported in the literature. However, while the number of remote laboratory initiatives is high, the overall impact of these laboratories is fairly limited beyond the scope of the host institution or the scope (and duration) of projects in which the host institution is involved.

In this contribution, existing efforts have been described from a technical perspective, and sharing economy platforms have been described, identifying some factors such as trust as key for their success. Thus, the contribution suggests that this factor must be included in any portal attempting to encourage adoption on the usage of remote laboratories beyond the scope of the host institution and related projects or direct relationships.

Finally, the contribution presents the LabsLand portal (as part of a spin-off of the research group called LabsLand), which attempts to provide these features so as to foster adoption of remote laboratory uses for achieving sustainability and maintainability of remote laboatories. The contribution describes the features and design philosophy of this portal. This portal will be used in the 2016-2017 course.

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