From a Hands-on Chemistry Lab to a Remote Chemistry Lab: Challenges and Constrains

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Abstract. The spread of remote labs in Universities is a current reality. They are strong e-learning tool which allow students to carry out online experiments over real equipment and Universities to have e-learning tools for learning methodologies such as Blended learning and Distance learning. These remote labs are developed for many science fields such as electronic, robotic and physic. Nevertheless it is very difficult to find chemistry remote labs. This paper wants to show the difficulties of choosing a chemistry lab which can become a remote chemistry lab, and a first approach of converting a hands-on chemistry lab to remote one.

Keywords: Blended and distance learning · E-learning tools · Hands-on and remote labs

1 Introduction

Traditionally, Students learnt theoretical knowledge in face to face classrooms and acquired skills from hands-on laboratories. But in the last decades, this idea has shifted from face to face classrooms and hands-on labs to online courses and virtual and remote labs.

Nowadays many universities provide virtual and remote labs where its students can carry out experiment from anyplace and anytime.

- Virtual labs are simulation programs which allow students carry out online experiments. There are a great number of them over Internet (Fig. 1), such as:
- Chemistry Labs. For instance Acid-bases solutions from https://phet.colorado.edu
- Physics Labs. For instance Newton's Cradle from http://www.myphysicslab.com/
- Electronic Labs. For instance basic digital labs from http://meteo.ieec.uned.es/www_Usumeteog/
- Remote labs are software programs which allow students to carry out experiments with real equipment at anytime and anyplace. In contrast to virtual labs, remote labs are working with real instruments [1–3]; therefore, the vast majority of them must control the access to lab (only one person at the same time). To do this, a set of services are created around the remote labs, such as: Control of users and Calendar.

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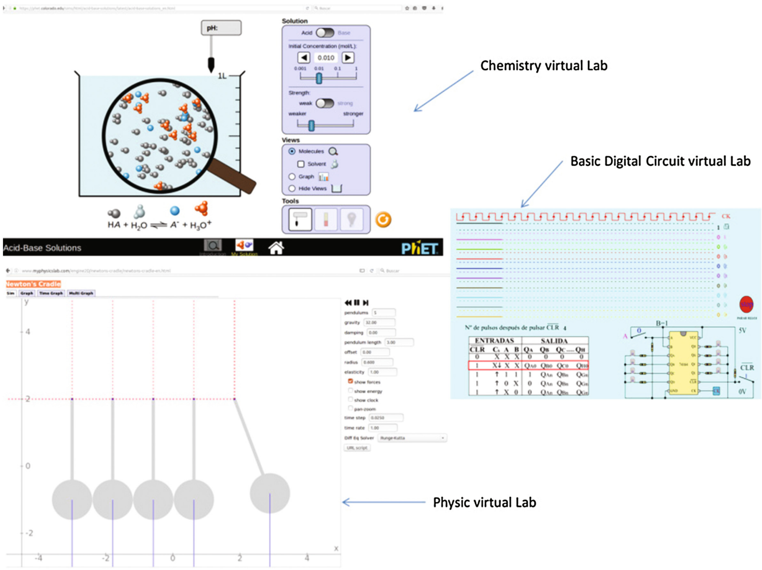

Fig. 1. Virtual labs or simulation web programs

These remote labs also cover a great number of science fields (Fig. 2), such as:

- Robotic labs. For instance i-robot lab from The Labshare Institute in Australia. This remote lab was designed to allow students to explore the concepts of teleoperation of robots, accuracy of sensors, localization and mapping [4]. Or the Robotic arm From UNED which allow students to work with a real robotic arm [5].
- Physic remote labs. For instance Archimedes remote labs from Deusto University where students of secondary school learn the Archimedes' Principle [6].
- Electronic remote labs. There are a lot of remote labs in this field. But, only two of them are going to be described:
  - The first one, is VISIR, this labs is really interesting for several reason: more than one user can access it at the same time, several universities has implemented this labs and are working together in project such as VISIR+ [7] and PILAR [8]. VISIR allows wiring and measuring of electronic circuits remotely on a virtual workbench that replicates physical circuit breadboards.
  - The second one is the Microelectronics Device Characterization remote lab. This Measures the DC current-voltage characteristics of microelectronics devices such as diodes and transistors [9].

This section showed several examples of virtual and remote labs in different science fields. The next sections is going to focus on describe briefly the architecture of remote labs and the difficulties to create chemistry remote labs due to its nature.

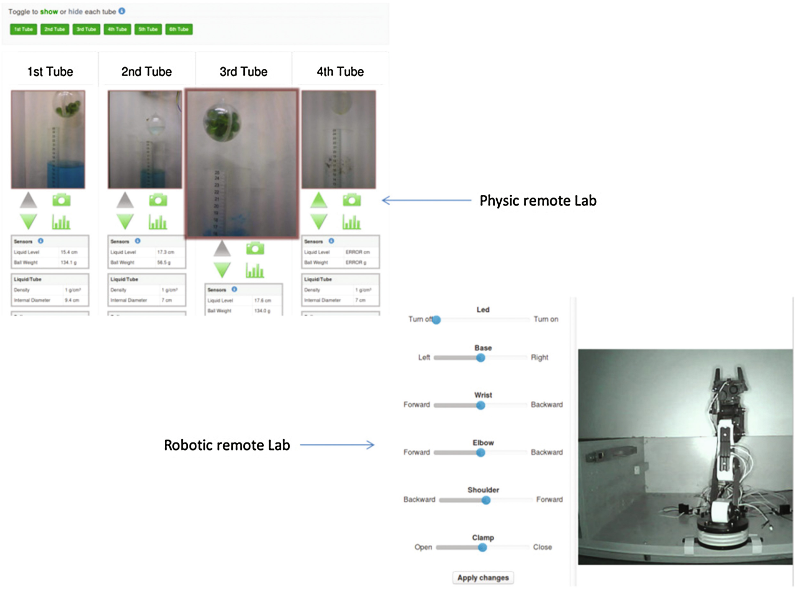

Fig. 2. Remote labs (real equipment)

2 Architecture of Remote Labs and Chemistry Experiments

The vast majority of remote labs are based on a same architecture. This is composed by:

- Web Server contains services such as control of users, calendar and user interfaces. It also communicates with user and the lab server.
- Lab server contains the program to act with the real equipment and send the result to web server.
- Real equipment depends on the remote labs. In the above section, it was shown real instrumentation such as robotic arm, electronic circuits, motors and pipettes.
- Web cam allows students to see the results of acting with the real equipment. Depending on web cam students can zoom in or out real instrumentation.

This is the hardware architecture but there are global phases that a remote lab should fulfill (Fig. 3). These Phases are:

- Initial state. Students must find the instrumentation in a state initial. For instance, in the Archimedes lab of Fig. 2 the balls must be out of the water or in VISIR lab the entries of the circuits must be in its initial state.
- Experimentation. This phase can be divides into other, such as action over the labs, storing student's actions over the equipment, storing results of these actions, etc.
- Results. Lab should show a report of results of the experiments
- Visualization. All what happens during the experimentation process must be watched by students through web cams, user interfaces, etc.

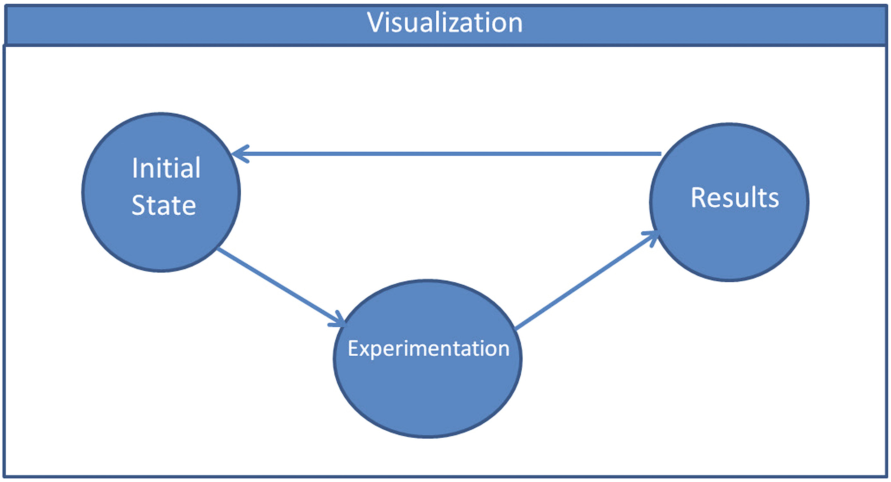

Fig. 3. Simplification of phases of remote lab

In the case of chemistry experimentation, several constrains are found in some of them phases. The following subsection will describe them briefly.

2.1 Constrains to Create Chemistry Remote Labs

Chemistry labs work with liquids, solids and gases. These resources are combined to create new ones. These experiments need a set of requirements that are really difficult in by phases of a remote lab.

- State initial:
  - Many chemistry laboratories works with fluids. These fluids are mixed and sometimes evaporated, therefore when students finish their experiments the fluids must be replaced and the instrumentation must be cleaned.
  - Many chemistry labs works with solids and liquids. These can vary his weight or volume. These can also mix giving as a result other chemical compound. Therefore, it is really difficult to give back an initial state without human help.
- Experimentation
  - Chemistry labs need handle and weigh solid material. For instance, the experiment of Reaction of zinc with iodine needs Zinc powder, about 0.5 g, sulfuric acid, about 20 cm^3, etc. Implementing the mechanics to do these measurements in an automatic way is really complicated.
- Visualization
  - Chemistry labs which work with gasses and transparent liquids are difficult to watch with web cams.
  - In some Chemistry labs, odors are also important for students. Remote labs are not able to provide this sense, although it is possible to use gas sensors.

All these reasons show the difficulties of designing and developing a chemistry remote laboratory.

3 Selecting Chemical Experiment

Once all these constrains were keeping in mind, the department of Electrical and Computer Engineering Department and Chemistry applied to engineering department from UNED decide to work in staring the conversion of the hands-on Hydrogen-solar equipment.

This equipment allows students to carry out hydrogen-solar energy cycle experiments. To do this, equipment provides a set of elements to convert water to hydrogen and oxygen, to store these in graduated Cylinders and to consume them in a fuel cell and produce electrical energy and water. This energy can be used to switch on a bulb or start a motor.

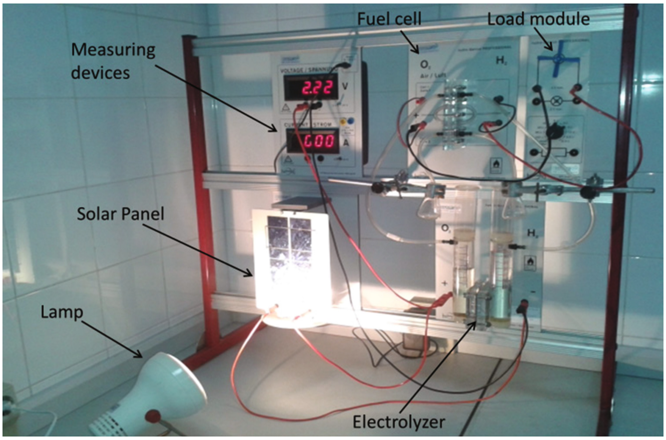

Fig. 4. Hydrogen-solar equipment.

As it has been told, the equipment is a set of hardware elements which allow performing this chemical process (Fig. 4). Among them:

- Light source. Sun is replaced by a lamp. This lamp simulates renewable energy. Students and teacher can move closer and farther the lamp to solar panel. This allows simulating the variation of light radiation on solar panel.
- Solar panel converts the light luminous energy, which is supplied by the lamp, into electrical energy. Students and teacher can vary the solar panel orientation and simulate different inclinations.
- Electrolyzer decomposes water into hydrogen and oxygen by using the electrical energy supplied by the solar panel.

- Fuel cell. It consists of two PEM fuel cells that can be connected in series or in parallel. They are used to generate electricity from the hydrogen and oxygen produced by the electrolyzer.
- Load module. It consists of an engine, a lamp and a set of resistors that allow using the electric energy generated by the fuel cell.
- Measuring devices. It is composed by a voltmeter and an ammeter to visualize the different voltages and intensities of the electric energy produced and consumed in each of the processes.

Although this lab requires to be filled with water for the initial state, the rest of the experimentation can be automated for blended and distance learning.

4 Hands-on Hydrogen-Solar Equipment to Remote Lab

This hand-on lab can be converted to remote labs. In this first step the department of electrical and computer of UNED has been focused on load module which can be replaced by an IoT device, such as Arduino and/or raspberry pi. These devices can manage a dimmer which can control the intensity of a lamp (Fig. 5).

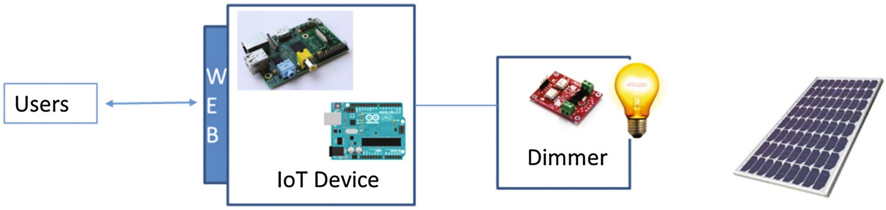

Fig. 5. Remote control of load module

Arduino and raspberry pi allow remote labs programmers to create a web page where students can change the intensity of the lamp.

Along with the modification of Load module a web cam connected directly to Ethernet will allow students to watch the real instrumentation and chemical process.

5 Conclusion

This paper shows the difficulties of creating chemistry labs. To do this, papers describes:

- A state of art of virtual and remote labs and some of the science field where are applied.
- Global architecture of remote labs and the phases of a remote lab.
- Constrains that have to be considered if someone wants to develop a chemistry remote lab.

- The selection of a chemistry lab that can minimize these constrains and will become a remote lab.
- And finally, the initial steps of the department of Electrical and Computer Engineering Department and Chemistry applied to engineering department from UNED to create a chemical remote lab.

Although a long road lies ahead, the first steps have been done.

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