Engaging Secondary School Students in Science by Developing Remote Laboratories

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Introduction

Technology-enhanced learning has become a new important trend in higher education worldwide, in particular in engineering education. Remote Laboratories - laboratories involving physical equipment that are available through the Internet – are an important part of this phenomenon and are constantly gaining motion in the higher education scenario. However, remote laboratories can also be effective assets in pre-university education. Several initiatives and projects have been or are being carried out worldwide aiming at exploring the use of remote and virtual laboratories by secondary school students. For example, the European Commission funded project Go-Lab (http://www.go-lab-project.eu/) is building a federation of Online Laboratories and tools to embed these labs in the lectures of secondary school teachers to serve as a motivation for students to pursue a career in STEM subjects. However, most of these projects treat students as consumers of Online Laboratories and not as providers or developers.

Background

It is practically impossible to imagine the study of natural sciences without laboratories where theoretical concepts can be verified. At the universities, this trend has been observed for several years. Engineers, for example, must learn during their education study how to communicate with nature in order to learn its principles[1]. Online Laboratories are tools for learning and research that make traditional laboratory workbenches available via the Internet and therefore reachable to a larger audience. Many laboratories require the manipulation of expensive equipment, what poses the first barrier against the practice of using traditional labs even more broadly, as not all universities and institutions can offer expensive labs. Even if the laboratory hardware is not expensive, many universities, especially in developing countries face an increasing number of students, what causes an increasing expenditure. In such a scenario, accommodating students in individual workbenches becomes impossible. Respecting students' individuality when carrying out an experiment is extremely important, learners usually come from different backgrounds with different knowledge.

Online Laboratories started gradually to gain motion after undergraduate distance education programs appeared[2,] however, only with the popularization of the Internet , the way distance education was carried out was changed. The uptake of Online Laboratories came a bit later. With the enhanced delivery of educational services through technological innovations and socio-economic factors, like the need for part-time study programs and continuing education have completely redefined the physical and temporal boundaries that education and laboratory experimentation have been subjected to[3]

At secondary schools, the use of laboratories is still not as present as at universities. During the last years some projects like Go-Lab (http://www.go-lab-project.eu/) and UniSchooLabS[4] (http://unischoolabs.eun.org/) have explored the use of Online Laboratories at primary and secondary schools as the mean to make the teaching of science more attractive for school students and thereby increase their interest for STEM subjects. The main motivation behind these initiatives are the several indicators that the interest for sciences and engineering appear early in our lives[5] and that in the near future a shortage of professional that pursued STEM careers might threaten the competitiveness of the future economies[6]. This trend is observed particularly for the US and European scenarios.

The initiatives mentioned above have in common, beyond their main goals, the use of the traditional paradigm of students solely considered consumers of learning resources. We believe that placing students in the role creators of these resources allows us to gain insights about their preferences and potentially improve the usability of these systems. Additionally, students were expected to provide feedback on the software framework developed in the scope of the project. This software framework aims at facilitating the task of plugging a new lab to the cloud.

The OnlineLabs4All Project

Building remote laboratories requires developers to deal with a highly interdisciplinary scenario. It requires a good understanding of information and communication technologies, computer sciences, management and additionally understanding of the laboratory domain (ex. Physics, chemistry, electronics, biology, etc) in order to be able to design experiments that can be conducted online.

In this work we flipped the roles and placed secondary school students as developers of Online Laboratories. Furthermore, placing secondary school students as developers allowed us to study their preferences and therefore acquire knowledge to build age appropriate user interfaces to control the Online Laboratory in order to make these more attractive and therefore improve the learning experiences.

Together with national and international partners we are carrying out a project that places students of technical secondary schools in Austria in the role of remote laboratory developers under the supervision and tutoring of the project staff. Students are actively involved in the scientific process and actively participate in the acquisition of knowledge.

The project pursues three main objectives:

1. Studies on age-appropriate requirements for the use of Online Laboratories at secondary schools.
2. Peer feedback to improve the user experience (usability) of the Online Laboratory UIs
3. Development of a software framework to facilitate development and deployment of Online Laboratories

The Software Framework

The details about software framework is outside the scope of this paper. We will provide an overview about its main functionalities. The software framework was designed to be used by Online Laboratory developers. It abstracts several complexities related to creating an educational Online Laboratory, such as:

- **Deployment of proper ICT infrastructure**: We introduce an Online Laboratory infrastructure as a service (LIaaS) paradigm that shifts part of the deployment of a traditional batched laboratory server to the cloud and exposes its functionalities via a simple set of well defined services.
- **NAT (Network address translation) traversal**: NAT enables several devices in a local network to share a single IP address. Most universities and private networks use

NAT to have all their devices connected to the Internet. This technique helped us to overcome the scarceness of public IP addresses, but on the other and it makes more complicated to initiate a connection to a device residing behind a NAT. Using the developed software framework a device can reside anywhere on the Internet.

- **Network Security (e.g. Firewalls)**: A simple set of services is provided over HTTP protocol using a RESTfull architectural style, allowing it to bypass firewalls and proxy servers.
- **Data Storage**: All the experiment generated data is stored in the cloud platform, so the developer does not need to implement it locally.

Fig. 1 depicts the software framework. It additionally communicates with well known remote laboratory management systems that deliver the laboratory client and the services supporting learning analytics and integration with learning management systems.

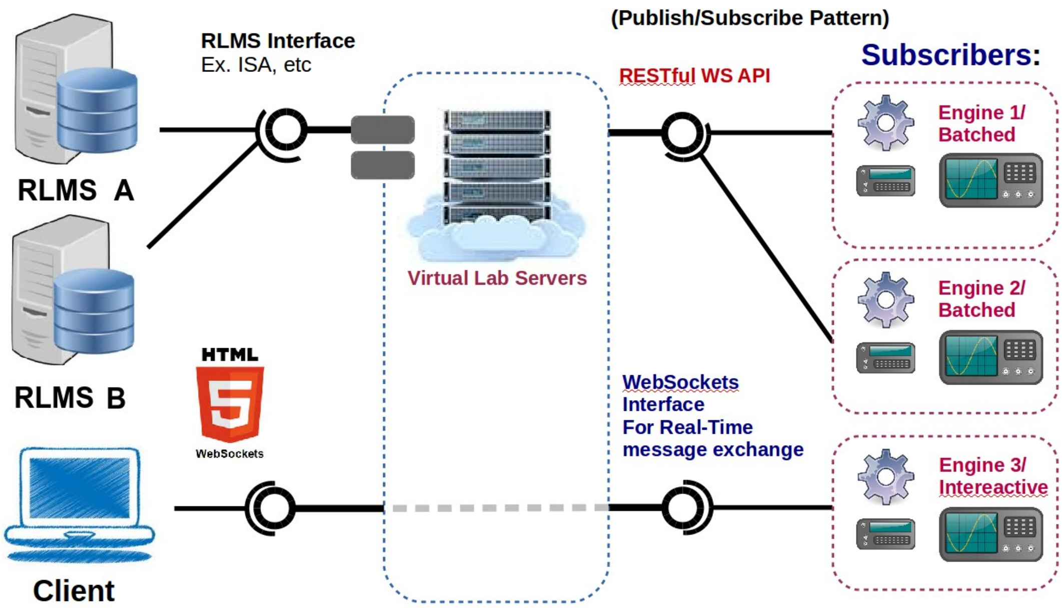

Figure 1. LIaaS software framework

The developed framework was named Experiment Dispatcher and it was designed to be a tool for laboratory developers. It does not replace any Learning Management System and Remote Laboratory Management System, but rather provides additional services to facilitate the development and deployment of new educational Online Laboratories and to plug them to existing RLMSs, like iLab Shared Architecture[7] and WebLab Deusto[8]. The main requirements for the development of the software framework were proposed in previous works[9,10].

The Online Laboratories Developed by Students

In this project we are working with three different secondary technical schools. In total, 10 students from informatics and engineering with ages between 17 and 18 are participating in the project. All three partners are Higher Technical Institutes (HTL) in Austria with a focus in technology and natural sciences. The courses last five years and students have to deliver a diploma thesis at the final year. For some of the students, the work carried out in the scope of our project served as subject for their thesis.

We began our research by constructing teams where each member had clear definitions of responsibilities. Each team had the task to develop a concept for an Online Laboratory in a domain of their choice. One team proposed a Remotely Controlled Warehouse System, the second developed two Online Laboratories in control systems and electronics and the third team created a laboratory for civil engineering that investigates how forces affect the deflection of a wood beam. The students were asked to create a mock-up of the user interface of the Online Laboratory and present it to the project staff. The process of bringing the laboratory online was carried out with close support of our team using a newly developed software framework (see Fig. 1) that simplifies this task.

In the initial phase, students were asked to design user interface mock-ups for the created concepts. The mock-ups were created using the online software myBalsamiq, which offers a friendly user interface that appeals to the students.

School 1 proposed a loaded support beam experiment to investigate how the forces affect the deflection of the beam and calculate tensile modulus of the material. The user will be able to control the horizontal position *x* and intensity of the applied force. The force measurement is done with a pressure sensor and the deformation of the beam will be determined by considering the change of pixels in the image captured by the webcam. Fig. 2 shows a mockup of the lab equipment.

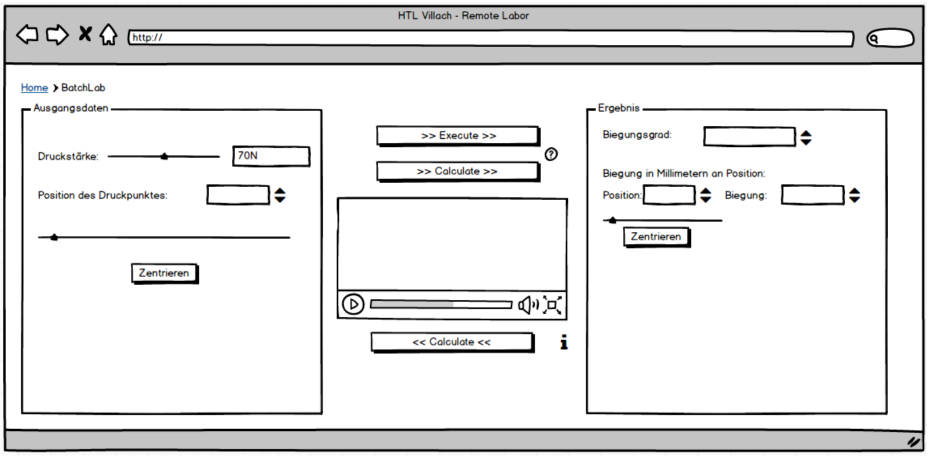

Figure 2. UI Mock-up of the loaded beam laboratory

On the left side the applied force and the x position can be set. The results can be observed via the webcam and the measured results can be seen on the right side of the UI. The webcam merely serves the purpose of showing that this is a real experiment and not a simulation. Based on mathematical models, it is possible to simulate the experiment. This possibility was additionally proposed by the students and will be implemented in the future.

School 2 proposed a control systems laboratory. The controlled system is an air tube with a ball. Users can remotely set the parameters of the controller and thereby control the vertical position *y* of the ball inside the tube. Furthermore, it is possible to change the constants of the controller. The lab client UI mock-up is depicted in Fig. 3

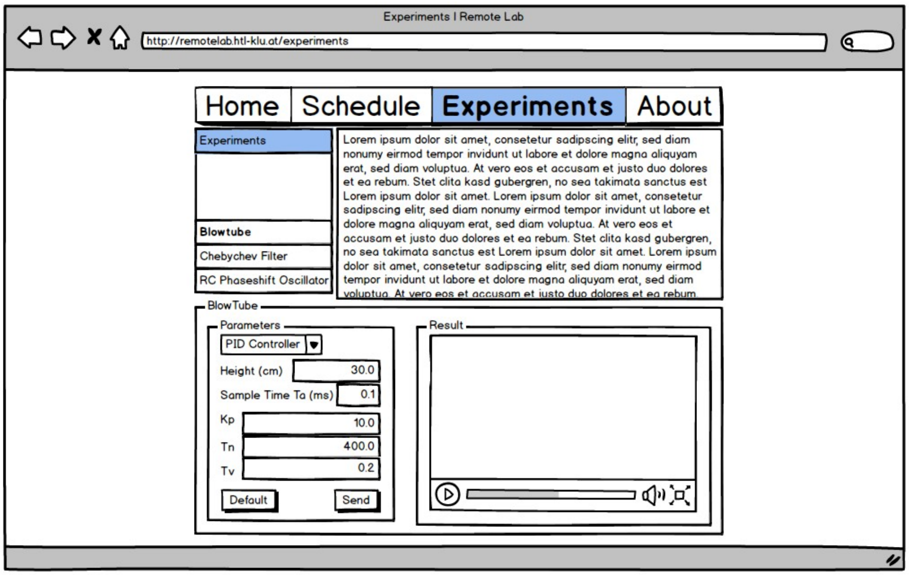

Figure 3. UI Mock-up of the control systems laboratory

School 3 proposed the implementation of a remote warehouse system. The concept includes a conveyer belt that carries balls of different colors. These balls have to be placed on different stacks based on the choice of the user controlling the system remotely. The system will be realised with Lego Mindstorms. The mock-up created by the students can be seen in Fig. 4

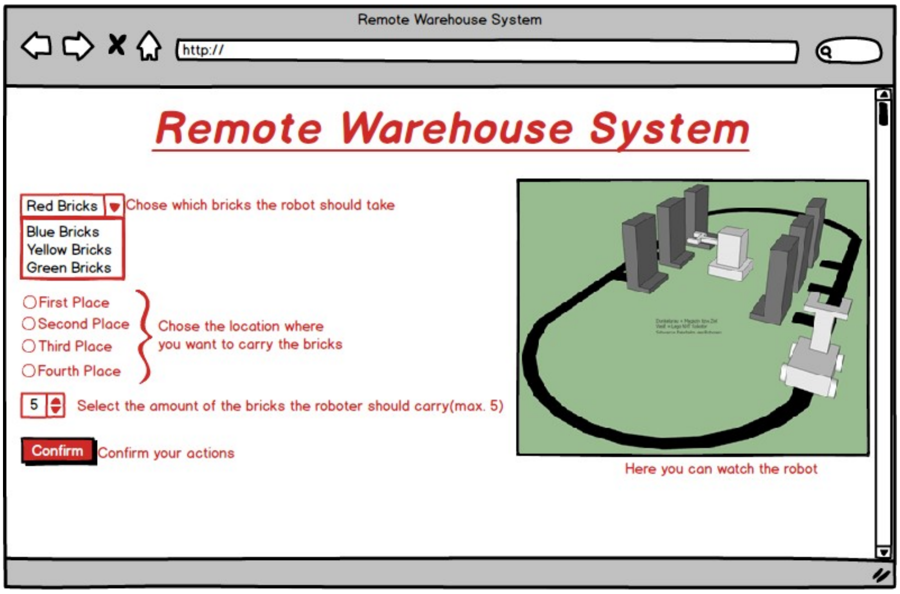

Figure 4. UI Mock-up of remote warehouse

The development of the Online Laboratories took place mostly at the student's schools with supervision of a team of teachers and periodical follow up by the up by the project coordinators. Students had the chance to work closely together with the team of the Carinthia University of Applied Sciences during a summer internship.

Conclusion

Several studies suggest that teachers and students of secondary schools can take enormous advantages of scientific inquiry methodologies[11,12]. Online Laboratories provide the learning tools necessary to carry out inquiry learning. In fact, the cases where Online Laboratory fails are those where not enough support was given to students when designing, carrying out and interpreting experimental data is provided. It is the task of the teachers to understand and implement the methodologies to achieve desired learning outcomes with Online Laboratories. We cannot expect that students understand these concepts and incorporate the pedagogical aspects into the developed UIs when asked to design an Online Laboratory.

As previously mentioned, developing an Online Laboratory requires students to familiarize themselves with a multidisciplinary field, often crossing the boundaries of their study curriculum. For example, students of informatics had to learn concepts of mechanics and civil engineering. Having to deal with problems like these brings them closer to the challenges that they are likely to face during their professional life.

One of the aims of this work and the primary focus of this paper is understanding the age-appropriate student preferences for the use of the laboratory experiments. This might have a positive impact on the usage and utilisation of Online Laboratories. After developing the user interfaces based on the mock-ups they had the chance to discuss with their peers from other partner schools and try the online labs developed by their colleagues. The project runs until November 2016. At the time of writing we are in the process of carrying out tests and a survey where the students will test labs developed by their peers. Results are expected to be available during the summer break.

In general, we value this self-paced student activity as a kind of inquiry and project-based learning. Students showed high engagement with the project objectives and clealy enjoyed participating. They had additionally the opportunity to work together with other peers from different schools also involved in the project.

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