

Overview on remote laboratories

- representative laboratories and projects in the electrical engineering domain -

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Abstract — *Laboratory work in Sciences and Engineering (S&E) courses is fundamental for practicing theoretical subjects. For this purpose, the conduction of experiments has been made using traditional laboratories, which provide local access to the equipment required to conduct and setup experiments. With recent technology developments, these traditional laboratories are being complemented with other laboratory types, like the so-called remote laboratories (or weblabs) that allow remotely accessing those same experiments. However, their implementation requires addressing educational and technical issues, as briefly described in this paper. For exemplifying recent trends on laboratory work supported by technology developments, some of the most disseminated remote laboratories in the electrical engineering domain are presented.*

Keywords: *Remote experimentation, remote laboratories, weblabs, practical work.*

I. INTRODUCTION

Technical skills acquired by current generations, oblige the adoption of new and innovative educational resources to capture students' interest and motivation for learning. Recent trends on education show that internet and associated services are playing an important role in this aspect. The traditional school with a teacher providing instruction in a common classroom is being complemented by a more personalized learning space, since the internet, and the high amount of information available, allow students to construct, at their pace, their own knowledge. As defended by the Problem Based Learning (PBL) theory [1], today the teacher must supervise and guide students rather than simply delivering information. Internet plays an important role by providing access to several educational resources like books, pictures, animations etc., giving more flexibility in students' learning outcomes. Today, the practical work, namely the laboratory work required by Sciences and Engineering (S&E) courses also benefit from this evolution, by the so-called remote experimentation concept that comprehends the use of remote laboratories (also named as weblabs) to conduct real experiments through the internet, with the same facilities provided by traditional laboratories.

Section II of this paper reviews the importance of laboratory work, and presents the available laboratory types together with advocators and detractors opinions about their adoption in educational contexts. Section III presents the advantages they bring to institutions, students and teachers. Section IV provides a general overview about educational and technical requirements that a remote laboratory should provide to the

laboratory work. Based on our knowledge and disseminated information, section V presents some of the most disseminated laboratories in electrical engineering domain, and section VI concludes the paper indicating a future direction for creating reconfigurable remote laboratory infrastructures.

II. BACKGROUND ON LABORATORY WORK AND LABORATORY TYPES

Practical work is fundamental in S&E courses providing students with the ability to understand theoretical subjects learned both in traditional classrooms and by their own research. Together with simulations and exercises, laboratory work (or experimental work) concerns a practical work element fundamental in S&E education that provides a strong impact on students' learning outcomes. Before the widespread of internet and associated services, laboratory work was fulfilled by traditional laboratories comprehending several instruments and experiments, able to access locally. Today, those laboratories are also called hands-on laboratories, since students are able to physically interact with the real equipment. Traditionally, they require from students all the experimental setup (e.g. connecting all the instruments to the experiment) usually not included in the new laboratory types that appeared with the technology evolution, namely the virtual/simulated, remote and hybrid laboratories. Hence, four laboratory types are now available for conducting laboratory work, each with specific characteristics, and having advocators and detractors opinions about their adoption in an educational context [2]:

- traditional laboratories (or hands-on laboratories) - students must be physically present in the laboratory to conduct and setup a specific experiment. Advocators argue that the interaction with real data and possible unexpected results are essential to understand the role of experiments, which is missing in virtual laboratories. Detractors indicate that experiments can be too costly since they can put high demand in space, instruction time and in the setup of the whole infrastructure. They also point that disabled and distant students have difficulties attending some experiments.
- virtual laboratories (or simulated laboratories) – by a PC, students may conduct experiments using equipment modeled by software. Spite of using models, which returns simulated results, advocators argue that the reduced expenses, and few amount of time that takes to learn using a