

Remote engineering laboratories for collaborative experiments

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ABSTRACT: Personal and professional attributes of university engineering graduates have become local and national priorities in Australia and elsewhere. These include communication skills, the management of information, a capacity for creation and innovation, commitment to professional and ethical responsibilities, leadership and team skills, capacity for lifelong learning and appropriate professional attitudes. This paper reports on selected collaborative remote engineering laboratory developments that can address some or all of the above competence items, and allow experiments to be conducted with partners sitting at the same computer next to each other or at computers dispersed around the world. The Internet enables the global collaboration and information interchange in social media and also in more professionally oriented remote engineering and science laboratories, where students may work together being geographically located elsewhere.

INTRODUCTION

Remote laboratories offer great opportunities for local students' worldwide access to facilities elsewhere in the city, in the country and in the world, the facilities being either unique, expensive, or allowing for interaction via the Internet [1-3]. Few remote laboratories offer a collaborative working environment, even though engineers collaborate either locally or in geographically dispersed projects in the real world. The NetLab is a unique collaborative working environment at the University of South Australia (UniSA) that allows up to three students to work together on an experiment [4][5].

The system would allow any number of students to collaborate, but it would be impractical, if all of them had control over the experimental setup. The NetLab has proved to be a highly successful remote laboratory, with thousands of users of the robust system for the nearly 10 years of its existence.

After a review of some existing remote laboratories (RLs) worldwide, the authors discuss student perceptions on real versus remote laboratories in the NetLab setting.

REMOTE COLLABORATIVE ENVIRONMENTS

Some examples of the remote collaborative laboratories are discussed in this section.

About 90 groups of three students each have been exposed to the remote experiment environment. The concentrated use of the remote laboratory during five academic semesters has definitely proved to be of high value for the 300 students per class and the instructors, in the course *Analogue and Digital Integrated Circuits* [6].

Remote interactive laboratory developments involve two or three students per group in the introductory and intermediate laboratories in face-to-face on-line on-site interaction between students and faculty. The on-line programs of RLs architecture design include fixed configurations and students' custom circuit design. The structure of the remote laboratory enables sharing of hardware and instrumentation resources.

MARVEL - a Leonardo da Vinci project (Virtual Laboratory in Mechatronics: Access to Remote and Virtual E-learning), with seven member institutions in Europe, has created a collaborative learning environment that helps to arrange on-line laboratories with simulation training and learning by doing it in mixed reality learning that offers flexible working hours, no safety concerns and a multicultural environment [7]. In part, it uses mixed reality experiments, where real devices work with simulation models on a collaborative e-learning platform.

The remote interactive laboratory was tailored to provide a constructivist pedagogical approach and a model for a collaborative learning environment [9]. The Masters of Engineering in Internetworking at Dalhousie University, Halifax, Nova Scotia, Canada, was a target of this experiment. The laboratory used *de-facto* networking standards, free software and a commercial Internet browser. The remote laboratories ensure the same quality of interaction as the current on-site facilities offer. The architecture design provides continuous assessment and real-time feedback to track the student performance.

REMOTE LABORATORIES

Remote laboratories have been seen as an alternative in times of increasing financial and physical strain on universities to provide adequate practical experience to engineering related courses. Remote laboratories aim to address many of the issues faced with the modern university laboratory experience [5], as they:

- Extend the students' learning experience by making more efficient use of their time;
- Increase the students' exposure to a greater range of laboratory equipment;
- Reduce costs, as the start-up costs of RLs are minimal compared with traditional laboratories and cater for a larger group of students;
- Give external students and students with physical disabilities the chance to conduct meaningful laboratory experiments;
- Allow students to collaborate without geographical limitations;
- Provide the ability for teaching material to be delivered/demonstrated locally and offshore.

REMOTE VERSUS REAL LABORATORIES

The most recent questionnaire was executed on the 30th May 2011, with UniSA students, who conducted experiments in a real laboratory and a remote laboratory, with a virtually identical experiment on RC Circuit Analysis in two different courses: Electrical Circuit Theory and Fundamentals of Analogue and Digital Electronics, has revealed interesting findings [4].

The majority of the students preferred the remote laboratory NetLab to the real laboratory. They have accepted that remote laboratories deliver learning outcomes and experiences that are equivalent to those delivered by real laboratories. They preferred to have a choice between using both laboratories, either alone or in conjunction with each other. They liked the NetLab because they had to solve the problems themselves, and they had fun at the same time. The answers to the question *feeling as if I was working in a real laboratory* was more divided, but do we want to be in a sweaty real environment instead?

The students liked the accessibility of the NetLab booking, the control of its equipment, easy access, and collaboration with other students, when wiring the circuit. They expressed confidence that more and more remote laboratories would be used in the future with virtual and augmented reality. They were comfortable with using the modern technology.

On the other side, the students wanted more access time to the remote laboratory, to use more functions of the oscilloscope, and supervisor's help (by definition not available).

In the real laboratory, the students did not like time consuming processes - finding the right equipment to work with, limited access time, faulty equipment, taking more time, no opportunity to repeat the experiment.

Other comments from the students praised using both the real and the remote laboratories to increase their skill and knowledge assimilation in a laboratory environment. Strong recommendation for using on-line and real laboratory at the same time was visible, as was commented by some students: *It was fun using both*.

CONCLUSIONS AND FUTURE WORK

Remote laboratories are demonstrably part of the 21st Century teaching and learning experimental environment, bringing the collaborative real environment to students' computers or other mobile devices.

Based on users' feedback, it would be advisable for the NetLab booking system, which at present limits access to three hours per week, to be amended to include a queuing system complementing the access when there is no pressure on the resource access.

It is clear that remote laboratories are becoming a substantial, and a significant, part of engineering curricula. Their use is on the increase and it will continue to be so.

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