Educational Technologies in STEM:

Remote Laboratories at RMIT University

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***Abstract*:** *Laboratories play a central role in the education of science, technology, engineering and mathematics (STEM) students. In recent years, the development of remote laboratories has become increasingly popular because they allow students to conduct real-time actual experiments remotely via the Internet. Using a computer located anywhere in the world students connect to the physical laboratory apparatus (called a "rig"), to manipulate the equipment, make observations and record results. Since 2007, the College of Science, Engineering and Health at RMIT University has offered remote laboratories to students located in Australia and more recently in Hong Kong. The intention is for these remote laboratories to complement the 'hands-on' laboratory experience, expand the range of laboratories available to students by sharing rigs with partner organisations, as well as provide students with the opportunity to conduct and re-run experiments at a time and location suitable to them. Our experience in the use of remote laboratories has shown that they enhance student learning through the engagement of students in laboratories to which they would otherwise have little or no access. Further, they offer genuine solutions to a number of issues facing educational programs as they enable ubiquitous, global access to educational and research infrastructure in efficient and sustainable ways, and they support research activities and collaborations across educational institutions, sectors and industry. RMIT University is one of the leading institutions taking a strategic approach with remote laboratories, nationally and internationally. The University is also a founding member of the Global Online Laboratory Consortium.*
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1. Introduction

Laboratory experience is essential to the teaching of science, technology, engineering and mathematics (STEM) disciplines. Most universities provide this experience in dedicated laboratory spaces designed to cater for the multiple sets of laboratory apparatus (or 'rigs') required to meet the learning needs of large student cohorts. These laboratories are onsite, and their use requires the student to be physically present to perform the experiment, as well as staff to set up, instruct and provide supervision during the exercise.

Delivering laboratories in this way however is becoming a challenge for universities. The rigs used in the laboratory can be expensive to acquire and maintain, and this limits the number and range of experiments available at any one institution. Further, there is often low usage of the rigs that are available, due to the restrictions imposed by student timetables and staff availability. The emergence of distance learning has also forced universities to re-think how laboratory-based experience could be provided to students who cannot be physically present in the laboratory.

These pressures faced by universities have led to changes in how laboratory experience is delivered. This includes demonstrations of concepts by a staff member to a class of students, or the provision of computer-based simulations (Corter et al., 2011). It could be argued however, that both demonstration and simulation defeat the original intent of experimentation because neither provides a student with the opportunity to interact with and manipulate the real laboratory equipment, in order to make personal and real-world observations. The 'remote laboratory' however, is a third option for universities to consider (Corter et al., 2011). Similar to the traditional laboratory, the remote laboratory requires real equipment; however it does not require the co-location of the student and the equipment. In this poster we

detail our experience in the delivery of remote laboratories to students enrolled in engineering programs on- and off-shore. We will show that this concept offers a real, cost-effective alternative to the delivery of laboratories on campus that also enhances the student's learning experience, while reducing the physical space and number of experimental rigs required.

2. What is a Remote Laboratory?

A remote laboratory is a real experiment, using real rigs that are accessed and controlled at a distance, using the Internet. To conduct the laboratory, students connect to the apparatus using a dedicated remote laboratory interface. They then manipulate the rig in real time, make observations and record their results for analysis. In many cases remote laboratories can be offered 24 hours a day, 7 days a week with minimal support from staff. This flexible arrangement with remote laboratories allows students to run and re-run experiments at a time and location suitable to them.

Remote laboratories are not replacement for physical laboratories; rather they complement the traditional laboratory concept. When used strategically, remote laboratories provide opportunities for universities and organisations to share rigs thereby maximizing efficiencies and reducing unnecessary duplication. This sharing allows students access to expensive laboratory equipment that otherwise would not be available to them, and reduces the physical space requirements for laboratories, as well as the number of rigs required by one institution. Remote laboratories also allow universities to provide students studying onshore, offshore or via distance learning, with equivalent access to real experiments anywhere a student has a computer and Internet connection.

3. The RMIT Experience

RMIT University (RMIT) is the largest tertiary institution in Australia and programs are offered from campuses in Melbourne and Vietnam, and via partnerships in Hong Kong, China, Malaysia and Singapore.

The first remote laboratory developed by RMIT was 'Characterization of Synchronous Power Generation'. This rig explores synchronous power generation and infinite bus, as well as the effects of varying prime mover power and field current on the generated power, voltage and current. The experiment is delivered using the iLab architecture developed by the Massachusetts Institute of Technology (MIT, 2012). This is a schedule-based interactive system suitable for expensive and one-off experimental rigs such as this. When required, the rig is made available to students over the Internet for two weeks, from 9.00am to 4.30pm each weekday.

This remote laboratory has been used every year since 2007. To date more than 350 onshore students and more than 200 students studying in Hong Kong have completed the laboratory remotely. Student feedback indicates that the remote laboratory concept has been well received. Student comments include: "It is a good start for RMIT to take this approach"; "It [remote delivery] made the laboratory more accessible"; and "The remote lab is a good idea. It was made available over 10 days."

In 2011, RMIT developed a second remote laboratory, 'Truss Testing'. Two identical rigs were built, and they allow students to observe forces induced in a common building structure and directly measure loading of the beams. Students access the rigs using the SAHARA interface developed in Australia by five universities, including RMIT. SAHARA uses a queuing system that is suitable for multiple rigs or experimental platforms. Students can login to the system, select a rig and perform their experiment. If both rigs are in use, students book a time to use the rig and then return to the interface and complete the remote laboratory in real time. Thirty minutes is allocated to each student, and they save their results to their own computer. Students write their laboratory report at a later time, and they can also re-book and repeat the experiment if they wish. To date, 380 RMIT students have completed this laboratory. The rig has been shared with 303 students from the University of Technology, Sydney. In addition, this remote laboratory was made available to high school students attending an information day at the University of Western Sydney (UWS) in 2012. Eighty-five students participated in the event and the feedback from UWS included: "We hoped that this event would advertise the benefit of remote labs to high school students and teachers alike… [T]he remote lab made our activity a success."

4. Future Directions

The success of the first two remote laboratories offered to electrical engineering students both on- and off-shore, has led to the development of eight new remote laboratory rigs during 2011/12. Three new engineering rigs, 'Speed Control', 'Engineering Geology' and 'Spectral Analysis of Rock Samples' have been created. In addition, five rigs have been created for use in applied science programs, namely 'E/M Ratio', 'Electron Diffraction', 'X-ray', 'Solar Cells Characterisation' and 'Doppler Effect'. The rigs for each of these remote laboratories have been built and they are in the final stages of testing. The intention is for these remote laboratories to be available via iLab and/or SAHARA by the end of 2012.

RMIT was one of the first universities in Australia to offer remote laboratories to students enrolled in engineering programs on- and off-shore. This development has enabled our programs to provide a similar laboratory experience to all learners at times that suit their needs, and regardless of their place of study. The creation of remote laboratories has also enabled the university to share rigs with other organisations, including interstate universities and high schools students.

References

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