International Collaboration in Remote Engineering Laboratories: an Approach to Development

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Abstract— This paper reports on a project that aims to develop, implement, evaluate and disseminate best practice in international on-line collaboration in remote laboratories, supported by a recently awarded Australian Learning and Teaching Council competitive grant. A remote laboratory (RL) is a computer-based learning environment that allows students from anywhere in the world to access and perform experiments on real laboratory equipment from a distance via the Internet. The experiments are not simulated and are not virtual. As such, RLs are excellent platforms for students to network and collaborate with students from other countries and through this interaction to learn skills that will prepare them for an international career in the global professional job market. The project creates a framework and a toolkit to be disseminated across the Australian higher education sector, and internationally, to be used to support student collaborative activities in RLs in a structured way that will enable students to develop intercultural communication skills and acquire the international perspectives sought by their profession.

Index Terms—Collaborative learning, engineering education, online learning, remote laboratories.

1 Introduction

The use of Remote Laboratories (RLs) has been trialled and supported at the University of South Australia (UniSA) furthering the University's commitment [1] to increasing student engagement through experiential learning (including practice-based learning, service learning and teaching-research nexus). The application of RLs reinforces a number of generic graduate qualities [2] including international perspective - one of the seven graduate qualities formulated by the University.

The project addresses the following priorities:

1. *Research and development focussing on issues of emerging and continuing importance*

This project focuses on teaching and learning issues of emerging and continuing importance that are confronting and will increasingly confront Australian universities over the next decade or so. These include international education and the internationalisation of the curriculum, flexible learning environments, problems over laboratory access and availability due to the growth of student numbers, increased use of specialised, unique and expensive equipment, etc. The project will equip graduates with knowledge and skills related to the collaboration of distributed international professional teams in a diverse global work environment.

2. *Strategic approaches to learning and teaching that address the increasing diversity of the student body*

Collaboration of students from different countries and cultures in remote laboratories will enhance students' international perspective, intercultural communication and skills in international collaboration using a unique approach of getting them to collaborate through their joint effort to conduct experiments on real equipment over the Internet. In educational terms the project will contribute to the development of the intercultural capability of graduates based on the concept of the Community of Practice [3] where individuals engage collectively in learning and problem solving, with minimal supervision – very much along the student-centred learning paradigm.

3. *Innovation in learning and teaching, including in relation to the role of new technologies*

Remote laboratories offer a unique Hi-Tech learning environment where students can remotely access and perform experiments on real equipment via the Internet. RLs are the latest developments that are reshaping the way in which courses with practical component are conducted. They already show some advantages

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over real and virtual laboratories [4] and are emerging as laboratories of the future. One certain advantage is the opportunity RLs offer for international student collaboration, which is simply impossible with conventional laboratories. The preparation of students for emerging forms of interaction that will characterise their future profession will be immensely important to their practice.

The project grant recently awarded by the Australian Learning and Teaching Council (AU$220.000 over 2008-2010), aims to develop, implement, evaluate and disseminate best practice in international on-line collaboration in remote laboratories (RLs).

This project is administered by the University of South Australia (UniSA) through the School of Electrical and Information Engineering. The project team includes the School of International Studies, UniSA, the University of Technology Sydney as an Australian partner, and two international partners, Faculty of Engineering, University of Porto (FEUP), Portugal, and Blekinge Institute of Technology, Sweden. Engineering disciplines in all four partner institutions have already developed and used RLs as modern Internet-based technology to support practical laboratory classes for their students.

All four partner institutions also have a strong interest in pedagogical issues emerging from this new technology. One such important issue is integrating individual RLs on a common worldwide computer network, which not only increases the pool of shared educational recourses, but also removes distance barriers and provides students in one country with the opportunity to collaborate on laboratory experiments and projects with students in other countries. The capacity of RLs to facilitate international collaboration of student cohorts is yet to be duly recognised and utilised to its full potential. The emerging importance of this attribute of RLs is seamlessly coupled with the emerging need for engineering graduates to be prepared to work within the modern collaborative international industrial environment.

2 Expected Outcomes

The main outcome of this project is a framework that will utilise RLs as an enabling medium for creating a student international perspective through the development of international collaboration and intercultural communication skills.

The project will be developed through a number of phases spanning over two years. The framework will initially be developed and implemented for two UniSA undergraduate courses: Electrical Circuit Theory (second year course) and Signals and Systems (third year course) and the corresponding courses at partner institutions. An assessment component will be introduced for these courses to permit quantification of student participation and learned skills. RLs will not be used for assessment; rather students will be submitting reports on assessment tasks which will be marked to form a component of summative assessment. These reports will also include student reflection and evaluation of their collaborative performance and skills in RLs. After evaluation of pilot trials with small numbers of students, it will be implemented for whole classes and evaluated. The work will be documented and disseminated in a form of guidelines for best practice accompanied by case studies that can be used by students and teaching staff. Although the project is aimed at engineering disciplines the resources will be applicable to other disciplines that include laboratory components in the curriculum.

3 Project Description

3.1 Rationale and Aims

The engineering profession has always highly valued collaborative skills in graduates. The increasing world economic globalisation, augmented by modern Internet technologies, requires engineering graduates to be prepared for work on international projects through a collaboration of distributed international professional teams in a diverse global work environment. This project addresses the need to develop these skills of emerging importance and will consequently enhance the competitiveness of Australian engineering graduates, and engineering profession in general, in the increasingly complex international job market.

3.2 Intercultural Capability

In this context, the engineering graduates need to be interculturally capable, that is, be able *to negotiate meanings* across languages and cultures [5]. This need has implications for the way we live our lives and interact with others, and for education at all levels [6]. In this sense internationalisation of higher education requires acknowledgement of the intercultural in both substance and process of change [7], [8], [9]. Not only do we need to understand the discipline as embodying knowledge of content, but also that this knowledge is embodied by people who have to interact professionally within the reality of multiple languages and cultures; that is, develop an intercultural capability. The development of this intercultural capability (as a graduate quality) requires an emphasis not only on additional content, but also on teaching and learning as a process, that is centred on individual interpretations and negotiations of meaning within and across disciplines.

The importance of developing an intercultural capability in this sense is supported in the literature [10], [11]. There is also agreement that intercultural communication requires recognition of the 'interculturality' of each communicator and how it contributes to intercultural teaching and learning [12], [13], [14]. Consequently, there is a clear need for contemporary students to become aware of the importance of the development and constant nurturing of this interculturality which will certainly underpin Australia's economic competitiveness and social openness as well as enabling opportunities for personal growth. The question is how to achieve this in a most effective way.

3.3 Communities of Practice

The core pedagogy of this project is based on the Com-

munity of Practice (CoP) concept [3], [15] defined as a network of individuals who engage in a process of collective learning in a domain of shared interest. Members of CoPs build relationships that enable them to learn from each other. In a CoP students can engage in a given professional, meaningful task and actively participate in problem solving. An RL constitutes a contemporary platform that enables CoPs to be formed among internationally distributed teams. The implementation of NetLab, the UniSA RL, has already been linked to improvement of student performance in the practical component of courses [4]. NetLab gives students flexibility to freely form groups and negotiate time for collaborating on experiments. Unlike in real (or so called proximal) laboratories, where students are often confined to a limited time, closely monitored by a supervisor and without an option to repeat experiment, RLs offer freedom to explore. But they also demand more responsibility from students for their own learning – a well known concept of student centred learning. Our experience shows that students mostly value RLs for the opportunity to repeat experiments whenever there is a discrepancy between their measurement data and their calculated results. This is reflected in better performance and grades in laboratory components of courses.

Based on this experience the project aims to capitalise on students' eagerness to invest extra effort and "do the best they can", when the educational environment offers the opportunity. This project aims to channel this effort into the development of international skills through forming CoP with students from different countries and different cultures while collaborating on remote experiments using RLs.

3.4 Collaborative Learning

Students' collaboration and cooperation skills can be acquired via conducting projects with an embedded remote experiment and working as a part of a team. Collaborative learning or cooperative learning, are forms of situated learning, which include group activities with emphasis on cooperation rather than competition among students [16]. These types require students to have additional skills such as the ability to work in groups. Cooperative learning is distinguished from collaborative learning. In cooperative learning teachers take most of the responsibility for decisions about what is to be studied and how the groups are to cooperate; while in collaborative non-competitive learning group activities, students are engaged in making decisions about what is learned and how [17].

Collaborative learning has been defined in a number of ways, but generally understood to refer to small group learning, where the group members actively support the learning processes of one another [16]. The introduction of the Internet has established a collaborative online environment [18]. The range of collaboration has thus advanced from the small group learning confined to the classroom or laboratory, to cyber-space, where the information and communication technology (ICT) has increasingly assumed a dominant importance [19].

Collaborative work has always been anchored in engineering practice as engineers seldom work in isolation. The success of large engineering projects depends on coherent collaborative engineering teams. Consequently collaborative learning is the most suited approach, indeed a must, in preparing engineering students for the challenges that lie ahead.

The Internet as a means of communication, collaboration and interaction among individuals as well as institutions of industry, commerce, education, government and science is invaluable. Today, the Internet is seen as one of the integral components of a global community and can be considered to be the major platform responsible for the formation of today's modern information technology reliant society.

3.5 Remote Laboratories

Globally distributed systems could and will be interconnected to function concurrently. Such systems will be controlled by international teams of specialists, also distributed worldwide. Members of these teams have to collaborate and communicate effectively to achieve the required objectives. Remote laboratories, which started their development about two decades ago, are currently seen as the humble beginning for future global systems. They represent a unique opportunity to develop a teaching and learning platform for the development of skills required for efficient collaboration and communication on a local and global scale. Currently there are about 120 RLs reported worldwide [20], yet only a few are constructed in such way to allow involved participants to collaborate in real-time as those RLs developed as part of the MARVEL (Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning) project [21], WebLab at MIT (Massachusetts Institute of Technology) [22] and UniSA RL called NetLab [4], [23];. However, a number of other institutions have recognised the advantages of collaborative RLs and are in the process of redeveloping their RLs into collaborative learning environment, e.g. our partner UTS, and the DIESEL (Distance Internet – Based Embedded System Experimental Laboratory) [24].

RLs are becoming common features of tertiary education environment. However, each RL is unique, different from others as there is no common standard that guides their development. However, our partner institution Blekinge Institute of Technology (BTH), Sweden has initiated an introduction of uniformity in both the architecture of RLs and the user interface (VISIR project). Their experience and contribution will be invaluable for the seamless integration of distributed RLs into a common worldwide computer network. Also, only recently the academic community began to initiate research into effective pedagogical strategies associated with the use of RLs [25].

On the other hand, very little research has been done on the evaluation of collaborative learning in RLs. This does not come as a surprise because a large majority of RLs are designed as single user laboratories and student collaboration is not possible. This contradicts professional engineering education practice where students normally perform laboratory experiments collaboratively in groups

of two or more students. However, the academic community recognises the importance of collaborative work in engineering profession, and thus in RLs [26] and recently there are proposals for developments of RLs as collaborative environments [27].

Remote laboratory NetLab is an interactive collaborative learning environment. Its initial development has been financially supported by a UniSA 2002 Teaching and Learning grant (AUD$40,000) [28] and later on the continuing basis by the UniSA School of Electrical and Information Engineering. Since 2003 it has been incorporated into the curriculum of a number of engineering courses [29], [30], and is currently used both by on-campus students as well as by offshore students enrolled in UniSA transnational programs in Singapore and Sri Lanka. Thus, opportunities for international collaboration already exist for UniSA students. This project will further develop resources for student induction and structured activities to ensure that student experience is positive and learning outcomes are effective. It will also broaden the pool of different cultures within CoPs to enrich student intercultural experience.

4 Outcomes and Deliverables

As stated in the Introduction, the main outcome will be the development of students' international and intercultural perspective through collaborative work with students from other countries remotely via the Internet.

The project will develop, implement, evaluate and recommend a framework that would best support student intercultural communication and international collaboration in remote laboratories (RL).

In the project implementation the framework will add strength to the learning and teaching level of universities, as well as in terms of project design, to integrate students more as partners than as objects, offering advice, feedback and making their own evaluations concerning the suitability of RLs as a medium for international collaboration. This will improve the communication and collaboration skills of local students as members of the Australian multicultural student body as well as those of their international collaborators. The project will develop assessment strategies to maximise the acquisition of collaborative skills. It will also advocate that future RLs be developed as interactive collaborative learning environments.

The key deliverable will be the development of a toolkit to be used both by remote laboratory developers and by university educators to support student learning experience through structured collaborative activities in RLs.

The outcomes of the project will be widely disseminated through the engagement of partner institutions, through publications, on-line discussion boards and workshops for targeted users of the developed material.

5 Approach

The proposed project builds on our extensive research and development of remote laboratories over many years at UniSA as well as on that of our colleagues at partner institutions. The UniSA remote laboratory NetLab is an interactive, collaborative learning environment and as such it offers a unique opportunity to lead this project. In addition, our off-shore programs delivered through Asia-Pacific-Management Institute APMI-Kaplan in Singapore allow us access a large number of international engineering students who use NetLab to perform the same experiments as the on-campus students in Australia. This will enable us to pilot the program with a small group initially and later, after initial evaluation, and implement it at a large scale under UniSA supervision. APMI-Kaplan employs only administrative staff and could not be involved as a partner on this project. It stands to reason that the involvement of partner institutions in Portugal and Sweden will be crucial to the success of the project. Recruiting students from their own institutions, and possibly from other European Community to collaborate in RLs with UniSA students, will increase the cultural diversity of the participating student body. It will also provide crucial insight into the experiences by students from other cultures that will be further used as a catalyst for guiding the directions of the project.

The UniSA RL NetLab, shown in Fig. 1, is situated in the Sir Charles Todd building at Mawson Lakes Campus in Adelaide. It can be accessed at URL: http://netlab.unisa.edu.au. Its hardware includes: the remote laboratory server, a number of other hardware items like 16x16 switching matrix, the web camera and various controllable instruments and components. Fig. 2 illustrates NetLab structure and access from remote locations.

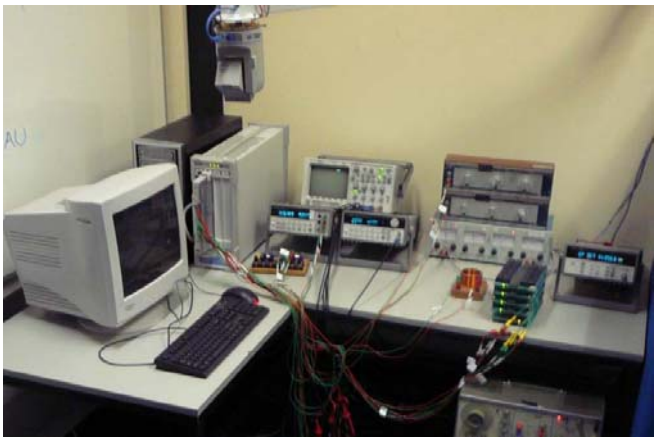

Fig. 1. The NetLab: UniSA remote laboratory

NetLab users create their own account by designating a username and a password, following which they can book a NetLab session using the time in their own time zone, which is then transcribed into the South Australian time zone. The online *User Guide* has 8 different video clips, each giving detailed description and help for the different components of the remote laboratory. Students can use NetLab individually or as a team of up to three concurrent users. All users have full control over the instruments in the laboratory via the NetLab GUI (Graphical User Interface) depicted in Fig. 3.

The booking system shown in Fig. 4 has been created

mainly to support international students booking NetLab sessions in their local time.

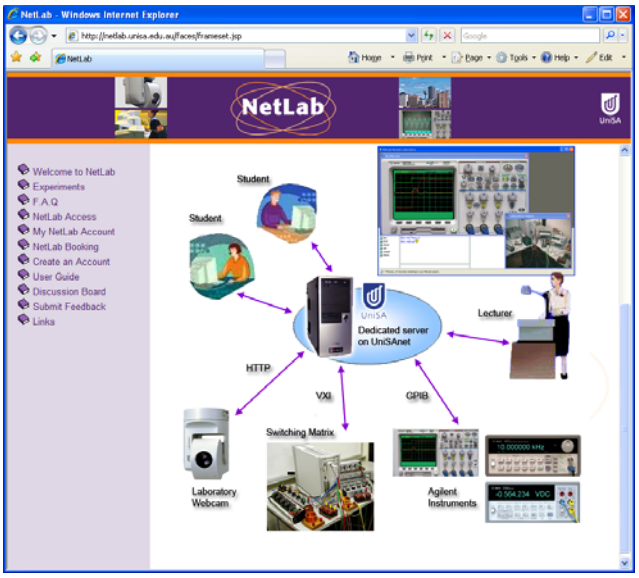

Fig. 2. The NetLab structure

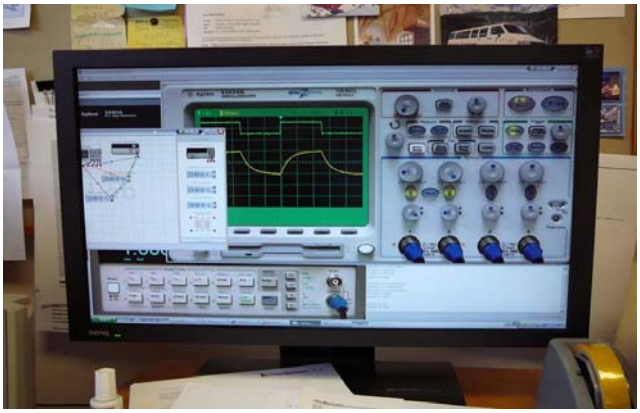

Fig. 3. The NetLab GUI on the user monitor

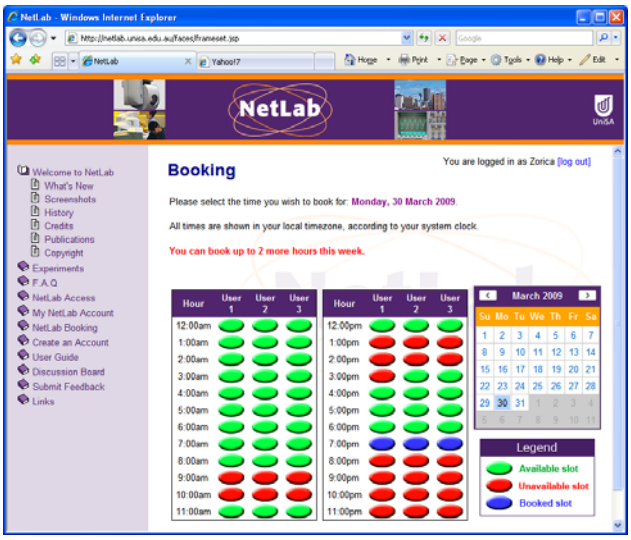

Fig. 4. The NetLab booking window as at 30 March 2009

6 Project Stages

The project is designed to proceed over the four stages outlined below. Each stage requires the research teams, representing partner institutions, to further the aims of the project in collaboration.. The ongoing national and international collaboration is seen as a key strength of the proposed project, building on the diverse and complementary skills of the partner institutions. The progress of the project will be evaluated through all of the four stages.

The first stage – Scoping:

The project team will review literature on benefits and obstacles in on-line collaborative learning, in the context of student collaborative work in an engineering laboratory. Information from this stage will guide the formation of focal points for developing a framework for teaching students on-line collaboration skills in an international environment.

Stage 2 - Aligning current system:

The project team will review the current best practice in the remote laboratories of the partner institutions with a view to aligning the RL environments of the partner institutions. UniSA remote laboratory NetLab uses only a text based communication (chat room) for coordination of activities of collaborating students. However, the partner institution, Faculty of Engineering, University of Porto (FEUP), Portugal has extensive experience in various types of audio-visual communication, which will be fundamental in selecting the most suitable means of communication in a RL. This stage will culminate in a recommendation for the most suitable type of communication system, including both hardware and software and taking into account issues such as technical and economic differences in the various partner localities.

Stage 3 – Development of the framework:

The project team will examine issues involved in international and intercultural communication between distant students who normally do not know each other and often do not share each other's linguistic and cultural expectations of the interaction. This stage will deliver an induction manual as a key component of the framework and resource for students and lecturers. The induction manual will support both students and their academic mentors in developing the capacity to interact interculturally in the RL environment. The induction manual will be developed through collaboration, locally and internationally with contributions from the research team, academics and students of the partner institutions in a process of participatory action research. This will involve cycles of action, observation, analysis, feedback and reflection, with the particular focus on the development of students' intercultural awareness and communication skills. Based on the accumulative findings of this process, the resulting induction manual will address linguistic and cultural norms associated with communication between students in the RL environment to develop their confidence in best practice in professional communication.

Stage 4 – Refining the framework:

The research team, in collaboration with the lecturers and students, will develop teaching and learning strate-

gies in line with the principles embedded in the induction manual. The development of these strategies will follow the same cycles of participatory action research and, together with the aligned communication systems and induction manual, constitute the framework for students and lecturers which will provide an effective learning environment in the form of a CoP where students will gain international collaborative skills while performing engineering experiments in remote laboratories.

7 Dissemination and Evaluation

All stages of the project will be disseminated and will be open to review, evaluation, contribution and implementation by partner institutions, the Reference Group and the wider academic community with the particular goal of adoption by the Australian university sector. A key part of this dissemination strategy is to inform and create awareness of the international experience developed through the project by effective dissemination through the Australian university sector and beyond.

Evaluation will be conducted by gathering information from surveys and focus groups consisting of students and lecturers from the four partner institutions by implementing trials with the participating classes. A NetLab Feedback Website will be available to students and lecturers at all times for disseminating feedback.

A Reference Group, consisting of national and international members, is being formed to be central to formative and summative evaluation of the project and its dissemination. The Reference Group will consist of representatives of Deans of Teaching and Learning of the four partner institutions and their academic leaders from engineering disciplines, national and international professional organisations such as Engineers Australia (IEAust), the Institution of Engineering and Technology (IET) and the Institute of Electrical and Electronic Engineers (IEEE) as well as lecturers and students participating in the project.

The dissemination and evaluation will occur throughout the duration of the project drawing on and engaging the extensive professional and academic networks of the project team. This process of dissemination and engagement will be further developed through workshops. The experience and outcomes from this current grant project will be an invaluable contribution to structuring collaborative activities and experiments in ways that maximise student learning outcomes in RLs.

The UniSA is entrusted with the responsibility to assume the role of the executive partner for all stages of the project development, implementation and dissemination. However, the role and the contribution of all partners are crucially important to the direction of the project, the quality of developed resources and their implementation, and the quality of the project outcomes in general.

8 Initial Implementation

The project required UniSA Ethics Committee approval before it could proceed. The required documentation was substantial and included research aims, methodology, timelines, list of participants, recording and storage of research data and results, and research tools (student profiles, post experiment questionnaire, information sheet for participants and student consent form). Written consent from all participating institutions, both Australian and international, was required to involve their students and staff.

During the initial meeting of all partners in Adelaide early in 2009, suggestions and input were solicited. These will be utilised in developing the details of the project plan, directions and distribution of tasks. The UniSA team members from the electrical engineering discipline will work closely with the UniSA team members from international studies discipline on the initial development of a framework which will then be circulated to partners for their reviews and inputs. The partner institutions will be responsible for recruiting and inducting students from their institutions to participate in the project by collaborating with UniSA students on jointly developed experiments. The partner institutions will supply feedback on their students' experience and provide suggestions on modifications to the framework.

Throughout the entire duration of the project all partners will contribute ideas, skills and activities that will maximise the effectiveness and success of the project outcomes.

A pilot trial is being conducted with small groups of students – 4 teams from Adelaide and 4 teams from Singapore. One of the first and unexpected findings in this project was that none of the student volunteers felt confident enough to work individually with students from other countries. Therefore we have two-to-two and two-to-three student teams.

Students in Adelaide have been trained in the use of Centra® [31], that is an excellent virtual learning environment in software with most of the features needed for the project including recording facility – critical for evaluation of student communication. The student feedback was positive; they enjoyed the training sessions and feel confident to meet with students in Singapore. Their first task is to introduce themselves and train Singaporean students in using Centra®.

After the trial a modified framework will be implemented for whole classes and evaluated as an ongoing part of the action research process. The findings will be documented and disseminated in a form of guidelines for best practice accompanied with case studies that can be used by students and teaching staff.

9 Conclusions

The paper presents a project that will support development of international online collaborative skills for engineering students in the context of using remote laboratories as a collaborative environment where students work together on laboratory experiments and small projects. During the process students are expected to develop communities of practice as one of the most effective learning environments.

Existing literature details the advantages that RLs of-

fer to all stakeholders involved in their deployment and use. To the student, these benefits include convenience, high availability, access to exotic or specialised equipment, self-paced learning and the removal of geographic disadvantage - to list but a few. This project, however, identifies yet another avenue for students to profit in the development of the skills sets they acquire from completing laboratory work remotely – that being an opportunity to learn from participating in a team exercise with students of differing locations, cultures, languages and work practices. The ability for professional engineers to collaborate in this context is an emerging and ongoing requirement and RLs can assist in equipping the next generation of students with the skills necessary to realise it.

The project will deliver outcomes in the form of a framework and a toolkit which will facilitate the adoption of laboratory learning exercises that foster international and intercultural collaborative learning experiences for participating students.

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