Collaboration in Remote Laboratory – vision for the future

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Abstract: - Worldwide globalisation trend goes hand in hand with the development of internet technologies that support international communication and collaboration. It is fair to expect that the international collaboration will soon include globally distributed engineering teams. Consequently, good international collaboration skills and experience in intercultural communication in engineering graduates will be highly valued by employers. This requires rethinking of engineering curriculum but also the development of modern technology that supports on-line collaborative environments and training students in using them. This paper presents a case study of collaboration in remote laboratory NetLab at the University of South Australia.

Key-Words: - remote laboratory, engineering education, on-line collaboration and communication

1 Introduction
Nowadays employers are seeking candidates with more than a strong academic record. Communication skills, problem solving ability and the capacity to work effectively in a team can be just as important as specific discipline knowledge. Consequently all programs at the University of South Australia are designed to develop seven Graduate Qualities that describe the knowledge, skills and personal abilities that allow our graduates to excel in the increasingly competitive global work market.

According to these qualities a graduate [1]:
1. operates effectively with and upon a body of knowledge of sufficient depth to begin professional practice
2. is prepared for life-long learning in pursuit of personal development and excellence in professional practice
3. is an effective problem solver, capable of applying logical, critical, and creative thinking to a range of problems
4. can work both autonomously and collaboratively as a professional
5. is committed to ethical action and social responsibility as a professional and citizen
6. communicates effectively in professional practice and as a member of the community
7. demonstrates international perspectives as a professional and as a citizen.

Graduate quality 5 requires graduates to develop collaboration skills. Collaboration is a process where two or more individuals work together toward a common goal. The classical example is a team work on a task or a project. If the project objectives are to be successfully achieved, all group members must collaborate in an effective way. This requires skills, which can be learnt by practicing the whole process of collaboration. These skills are essential skills highly valued by employers of university graduates.

The collaboration skills can be acquired during the team projects required to be completed during the undergraduate engineering studies. As a simple example, we can consider a team work on a practical experiment in an engineering laboratory. This requires three stages: the preparation, the execution of the experiment and post experiment stage of the analysis and the report writing. This is a general example of an experiment with different stages of collaboration. Pre-experiment and post-experiment stages are mostly conducted in an asynchronous way, where students split tasks and then compile results together. However, the stage of performing the experiment is the real time collaboration task. Students work on the experiment in a laboratory together as a group usually under a supervision of an instructor.

If not already, in the very near future the collaboration will advance to the international level, following the development of the global network of interconnected computers and other engineering systems. Not only the systems will be distributed and interconnected worldwide, but they will be controlled by also globally distributed teams of professionals. This requires the development of good international
collaboration and communication skills of all professionals involved in such enterprise.

The collaboration skills learnt during engineering studies are mostly developed among local students working on team projects and during practical sessions in the laboratory. To develop global international collaborative skills, a different approach is needed. In the School of Electrical and Information Engineering (EIE) at the University of South Australia (UniSA), a remote laboratory NetLab has been developed in such way to support learning collaborative skills required for the international teamwork. Remote laboratories (RLs) allow users to access real equipment and perform experiments remotely via the internet. The RL NetLab is designed and implemented in an interactive collaborative mode, which allows up to three students to collaborate on an experiment. In this paper we describe how the RL NetLab, which has been incorporated into curriculum of a number of engineering courses [2], enables students and visitors from different locations to conduct experiments in a collaborative way.

2 Collaborative RLs

Currently there are more than 120 RLs worldwide[3], yet only a few are constructed in such a way to allow participants to collaborate in real time. The collaborative RLs include the NetLab at UniSA [4], RLs developed as part of the MARVELL project (Virtual Laboratory in Mechatronics: Access to Remote and Virtual e-Learning) [5], DIESEL project (Distance Internet – Based Embedded System Experimental Laboratory) [6], the WebLab at MIT (Massachusetts Institute of Technology) [7] and the Collaborative Remote Laboratory at the University of Saint-Etienne [8].

The UniSA delivered its first offshore programs 13 years ago. They have grown rapidly in numbers and at present the UniSA Schools are engaged in more than 100 transnational programs in Hong Kong, Malaysia, PR China, Singapore, Sri Lanka, Switzerland, Taiwan and Thailand [9]. Currently, the School of EIE is involved in three transnational programs. These programs are associated with the International Kolej Bandar Utama (KBU) in Malaysia, with the Colombo International Nautical & Engineering College (CINEC) in Sri Lanka and with the Asia Pacific Management Institute (APMI) Kaplan Higher Education in Singapore with more than 400 students.

The use of RL NetLab is crucial in delivering our transnational programs at APMI Kaplan in Singapore as local laboratory facilities are not available. Also, as a collaborative environment, NetLab offers an excellent opportunity for Singaporean students and students in Adelaide to collaborate on same experiments and develop international collaboration skills within an online environment.

To accomplish this role, the NetLab not only provides remote access to laboratory equipment, but also means of communication among participants. Fig. 1 shows the NetLab graphical user interface (GUI) with a chat room in its lower left-hand corner.

NetLab GUI is the most distinctive part of this RL. From the beginning of its development it has been designed with the intention of giving students the feel of working in a real laboratory as much as possible. When the NetLab is accessed, the client software is downloaded onto the user computer, which requires the Java runtime environment to be installed on it. The client software opens the NetLab GUI shown in Figure B, which includes a video image of the real environment through the web camera.

The main features that support this realistic interface through the GUI are:

- Animated photographic images of instruments
  Students interact with instruments by pushing and turning buttons on animated images of the instrument control panels. The button responses are animated (they turn or light up, etc) in the same way as on the real instrument to give student immediate feedback to his/her action. The only difference is that students use the mouse instead of their fingers to control instruments. The measurement results are imported from real instruments and displayed on the animated instrument control panel in the GUI.

- Chat window
  It has been already mentioned that NetLab is a multiuser, collaborative learning environment where up to three students can work on the same experiment at the same time in addition to an unlimited number of students in real time. To have real-time communication, the NetLab allows up to three users to connect and chat with each other. The chat window allows students to communicate in real-time with other students or teachers, share ideas, discuss experiments, and give immediate feedback to each other.

- Remote access to laboratory equipment
  The NetLab provides remote access to laboratory equipment, allowing students to perform experiments from anywhere in the world. The equipment is controlled through the GUI, and students can view the results on the animated control panel. This feature is especially useful for students who cannot visit the laboratory in person, providing them with an opportunity to participate in experiments and learn from a distance.

- Interactive collaborative mode
  The NetLab is designed and implemented in an interactive collaborative mode, allowing up to three students to collaborate on the same experiment at the same time. This feature is essential for developing collaboration and communication skills among students from different locations. The students can share ideas, discuss experiments, and give immediate feedback to each other, promoting a collaborative learning environment.

- Video image of the real environment
  The NetLab includes a video image of the real environment through the web camera. This feature allows students to see the laboratory environment in real-time, providing them with a realistic experience of working in a real laboratory. The video image enhances the learning experience and helps students understand the practical aspects of the experiments.

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administrators/lecturers. The system automatically displays names of all logged-on users, including administrators, so students can easily detect the presence of a lecturer or another administrator who can help them if they need assistance. The communication between distant users is in text form via the chat. Although it is a simplest communication tool it is very efficient in terms of bandwidth occupancy and in many cases may be clearer than voice communication. However, student feedback shows they would prefer to have voice and video communication and currently we are trying to select a suitable tool among many existing options, some of them already employed in other collaborative RLs [6, 9].

Control window
In a collaborative environment users do not see each other and thus cannot monitor each other’s action. NetLab gives full control over the system to all users. Confusion may arise as to whether someone is inadvertently pressing buttons or the system is not working properly. To prevent this, the NetLab GUI includes a control window in its bottom right-hand corner as shown in Fig. 1, which broadcasts the actions of all users. Other systems use color-coding of users to broadcast actions by different users[8].

Telepresence via the web camera
Students have full control of a web camera and can view instruments and components or just look around the laboratory. The NetLab camera provides an option to preprogram 10 positions. This is very useful as students can view different instrument by simply selecting them from the camera menu. We believe that a camera is an important part of every remote laboratory, in order to give students the feeling of presence in the laboratory. Otherwise the interaction between a student and the system would be the same as in the case of simulation. Our experience and surveys show that students like to use the camera, sometimes just for fun, but more often to make sure the instruments in the real lab respond to their actions.

The NetLab booking system
The system requires each new user to create an account and then to book a session. As a multiuser collaborative environment, NetLab allows more than one user to have full control of the system at the same time. However, the number of concurrent users is now limited to three. The flexibility of the system allows each student to book 1, 2 or 3 seats in each 1 hour session, so that the students can work in groups of 3 or 2, or alone. To prevent excessive booking, a lecturer (administrator) can set a limit on a number of hours per week that each student can book.

When the mouse is positioned over a booked time slot, the user name and his/her country (except Australia as a default) is displayed. This provides students with an option to choose a laboratory partner from another country. An unlimited number of users with administrative privileges can access and control the system at any time without booking even if three other users are logged on. All booking are done according the local time zone installed on the user’s computer. Fig. 2 shows Singapore view of bookings for 15/03/2009. Fig. 3 shows the Adelaide view of the same booking with a 2.5 hours time difference.

Fig. 2. NetLab booking for Sunday 15/03/2009 in Singapore.

Fig. 3. NetLab booking for Sunday 15/03/2009 in Adelaide.

3 Collaboration project
The importance of the development of international collaboration skills is recognized by Australian Government by funding of AUD$220,000 for the project Enriching Student Learning Experience through International Collaboration in Remote Laboratories through the national competitive grant Australian Learning and Teaching Council (ALTC) Grant. The project involves four partner institutions, two from Australia, UniSA and the University of Technology Sydney (UTS), and two from Europe; the Blekinge
Institute of Technology, Sweden and the University of Porto, Portugal. Apart from the School of EIE, the School of International Studies is involved UniSA bringing the expertise in multicultural communication to the project.

The project aims to develop a framework to support teaching and learning international collaboration and intercultural communication skills in remote laboratories. The project is in its initial stage that involves observation of how students interact with members of their distributed team with an intention to find where intervention is needed to improve this interaction. For this purpose pilot groups are formed with two students working in Adelaide and the other two students working in Singapore. Students are collaborating on a sample experiment that involves analysis of a 3\textsuperscript{rd} order electrical circuit as part of the 3\textsuperscript{rd} year course Signals and Systems (code EEET 1015). They are expected to meet several times in order:

- to prepare for the experiment by analysing the circuit using calculation and simulations
- to conduct the experiment using NetLab RL
- to perform post-experiment analysis and to write the group report.

Students are given full freedom when and how to collaborate, but are asked to make recordings of all sessions. For this purpose the Centra\textsuperscript{®} software developed by Saba\textsuperscript{®} company is used because it supports:

- text, voice and video communication
- shared whiteboard with drawing tools
- sharing active applications like PSpice, MATLAB, NetLab, etc.
- recording sessions

In addition, it is easy to operate and to schedule meetings. It allows all participants to be promoted to “presenter level” authorising all students in the team to have a full control over the system. A screen capture from a recorded Centra\textsuperscript{®} training session is shown in Fig. 4.

Centra\textsuperscript{®} is an excellent virtual learning environment, but it is not expected to be used as part of the framework for student collaboration in the future. Instead, a suitable software will be selected. The selection will depend on the outcomes of the ALTC project as the best collaboration environment is yet to be determined as part of this project. However, it is used in this pilot project because it is available at UniSA and has most of the features needed for the project including recording facility.

So far only training sessions have been conducted with students volunteering for the ALTC project in Adelaide. The students’ feedback was positive; they enjoyed these sessions and feel confident to meet with students in Singapore. Their first task is to introduce themselves and train Singaporean students in using Centra\textsuperscript{®}.

4 Conclusions

In this paper we presented remote laboratory NetLab as a collaborative learning environment which will be used to develop international collaboration and intercultural communication skills in undergraduate engineering students at UniSA and other countries. The outcomes of the project are expected to influence future RLS to be developed as collaborative systems which goes hand in hand with the nature of a modern engineering work environment.

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