Collaborative Learning in the Remote Laboratory NetLab

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ABSTRACT

At the University of South Australia (UniSA) the practical component of engineering education is considered to be a vital factor in developing university graduate qualities [1]. Practical experiments performed in laboratory facilitate students' abilities to apply their knowledge, work collaboratively, control equipment and analyse the measured data. The remote laboratory NetLab has been developed within the School of Electrical and Information Engineering (EIE). A fully functional system has been used by up to 200 onshore and offshore students to conduct remote experiments every year since 2003. This paper describes the remote laboratory and discusses how collaborative team oriented tasks can be conducted in the online environment. The functionality of NetLab is demonstrated by an example of a remote experiment.

Keywords: NetLab, remote experiments, and collaborative learning

1. INTRODUCTION

One of the main requirements of 21 century society is to have highly developed professionals, who are able to work as a team. The introduction of e – environment with its fast development in the past decade, individuals are required to work and collaborate regardless of their global positions. For example a project to be accomplished in Australia would require involvement of team members from other continents. This requires that professionals, who are a product of higher education institutions, are equipped with specific skills and qualities to enable them to work collaboratively online. The University of South Australia is well aware about this requirement and its teaching and learning strategy has been modified accordingly. The remote laboratory NetLab, funded by the University teaching grant of $40,000 in 2002 [2], has been developed and implemented under the authors' supervision by senior undergraduate and postgraduate students [3]. For science and engineering professionals, the laboratory part of their tertiary education is very important to reinforce learning of theoretical concepts and provide the translation from theory into practical understanding. During this process students are also developing collaborative skills, as they usually work in teams. But the traditional approach to practical sessions in the real laboratories is changing dramatically with new available technologies and with remote laboratories spreading worldwide [4, 5]. The Internet has enabled conducting of real experiments at any time at any location. However, the question arises: Can remote experiments develop collaborative students' skills in the same way or even better as traditional real experiments? All authors have been very active education researchers in the past, always trying to implement the newest available technologies and teaching methodologies. They have implemented more than 10 teaching and learning innovative projects supported by UniSA. This paper is focused on their most successful project, the remote laboratory NetLab, respective discussing and demonstrating NetLab impact on student collaborative learning.

2. COLLABORATIVE LEARNING

Collaborative learning or cooperative learning are types of situated learning, that include group activities with emphasise on cooperation rather competition among students. These types require students to have additional skill such as the ability to work in groups. Cooperative learning is distinguished from collaborative learning. In cooperative learning teachers take most of 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 [6]. Collaborative learning has been defined in a number ways, but generally understood to refer to small group learning, where the group members actively support the learning processes of one another [7]. The introduction of the Internet also established online cooperative environment [8]. The range from the small group learning confined to the classroom or laboratory,

advanced to the cyber space, where the computing and information technology increasingly assumed a dominant importance [9]. Collaborative work is has always been anchored in engineering practice, as engineers seldom work in isolation. Great engineering projects must be created by a team of engineers and consequently collaborative learning is most suited and a natural must in preparing engineering students for the challenges that lie ahead.
The application of collaborative learning approaches is a highly valued scholarly activity which the UniSA encourages and facilitates in various ways including through teaching awards, promotions criteria and professional development activities.

3. LABORATORY EXPERIMENTS IN THE ENGINEERING EDUCATION

One of the most important factors in forming the engineering graduate qualities is the practical component of the engineering curriculum. The professional engineering community expects engineering graduates to develop practical skills during their undergraduate educational experience. Work in the engineering laboratory environment provides students with opportunities:

- to test conceptual knowledge
- to work collaboratively
- to interact with equipment
- to learn by trial and error
- to perform analysis on experimental data

The practical component can be conducted in the form of a real experiment in the real laboratory, in the form of simulated experiment or in the form of remote laboratory experiment. Many software packages have been developed for the simulation of real experiments and although very useful, none of them are as effective as learning from undertaking real experimental work.

During the last decade the exponential expansion of the Internet has had an enormous impact on the tertiary education sector. Yet in the beginning the Internet was not considered to be suitable for learning, as providing students with information on line is not sufficient for learning [10]. But the new technology has brought a significant improvement in communication within the academic community and also has brought an opportunity to create systems which enable students to conduct remote experiments at any time at any distance. Students are performing experiments using real devices and components in the real laboratory via the Internet. Comparative studies have been conducted comparing advantages and disadvantages of all three modes of laboratory experiments, real, simulated and remote experiments [11-13]. It has been investigated and documented that remote laboratories provide similar learning outcomes, if not better, to their class analogues [14].

4. REMOTE LABORATORY NETLAB

The NetLab, located at http://netlab.unisa.edu.au/, allows lecturers and students to interact with real equipment located elsewhere, via the use of the Internet from a computer, which could be in a lecture theatre, office or at home as shown in Figure 1. From the year 2003 the NetLab was integrated into three undergraduate courses. The whole system is still under development to enhance the existing features [15, 16]. To improve students' learning outcomes regular feedback responses are acquired from students, evaluated and later used to modify the system. Not only are university staff and students able to access NetLab, but also the general public can access the system as visitors after registering. The system is able to be accessed at any time from any location that has a PC with an Internet connection. This allows students to conduct experiments outside of university hours and lecturers are able to easily include practical demonstrations in their lectures.

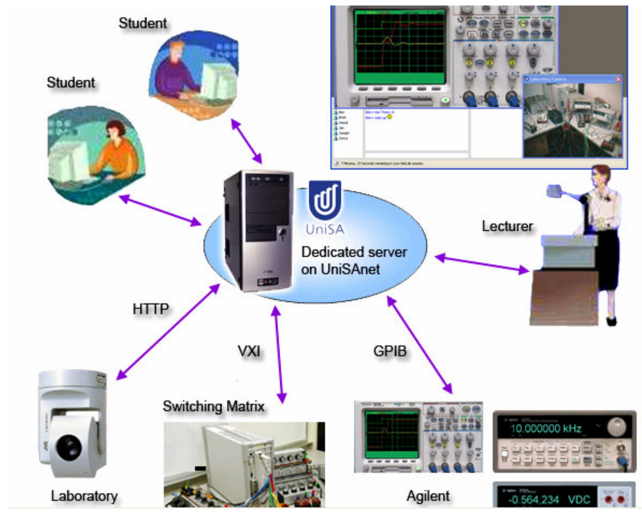

Figure 1. NetLab architecture

The NetLab server is located in a locked room at the University of South Australia. The real equipment is connected to the NetLab server via an IEEE 4888.2 interface, otherwise known as GPIB (General Purpose Interface Bus). The server is also connected to the Internet. A photograph of the laboratory equipment is shown in Figure 2.

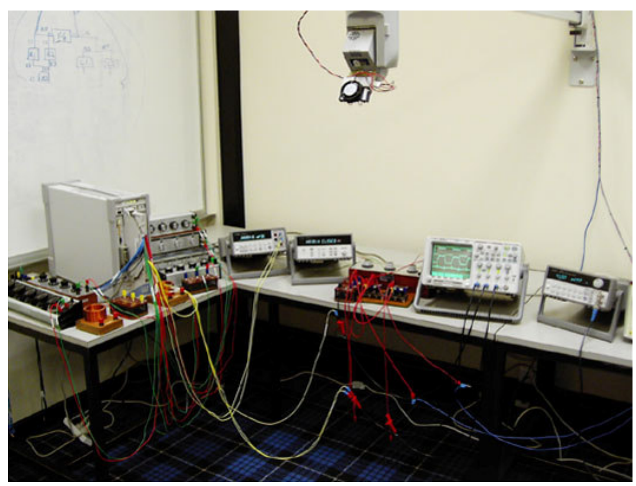

Figure 2. NetLab real equipment

NetLab's Graphical User Interface (GUI) is written in Java; hence the Java Runtime Environment (JRE) must be installed to allow the NetLab application to run. The user can control the real instruments through the client software, consisting of the interactive GUI. The users' commands are then sent to the NetLab server and processed by the server software, originally written in LabVIEW but redeveloped using Java in 2006, The

NetLab server uses an implementation of the Virtual Instrumentation Software Architecture (VISA) Application Programming Interface (API) to direct the commands to the appropriate programmable instrument. The VISA API allows software to communicate with a variety of hardware devices, using a variety of connection, from the same software interface. The instruments are connected through an industry standard General Purpose Interface Bus (GPIB) port. This same GPIB port is used to retrieve the relevant data from the instruments and passed on to all connected users. This data, such as the data points acquired with the oscilloscope, can then be exported to a file for use with relevant software such as MATLAB (a software package from MathWorks) for further analysis.

The main client Graphical User Interface (GUI) is shown in Figure 3. The all windows frames are available from the drop down main bar at the top. Under Instruments there are all GUIs of available instruments which students can choose and use to conduct an experiment. The GUI of the specially developed software of the Circuit Builder is also located there. It allows electrical circuits to be wired and configured remotely. When activated, students are able to configure their own circuit required for the experiment and then they can send their configuration to the NetLab, where the real components and devices are then connected exactly in the same way via the relay matrix switch [15]. Under Camera there is a camera window available with the real live video image and camera control movement buttons. In the left low bottom corner there is window showing all present users names. A chat window which enables a students' communication is located in the middle bottom panel. The notification pane, located at the bottom right of the GUI, broadcasts the interacting actions taken by all of the users to ensure that other users in the group can see the instruments' status and are aware of any changes that are made to instruments' settings.

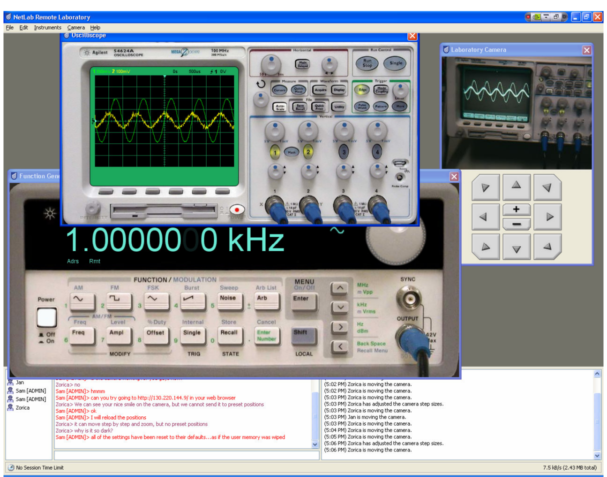

Figure 4: Main Graphical User Interface of NetLab

The GUIs of NetLab instruments are created from photographic images of the instruments' front panels. A click on one of the instrument images brings up a larger interactive image of that instrument giving increased readability. Figure 4. shows an example of the resulting window when the oscilloscope is clicked on, which contains an interactive image of the oscilloscope that is approximately 1:1 ratio, on a standard 17" monitor, with the size of the physical oscilloscope.

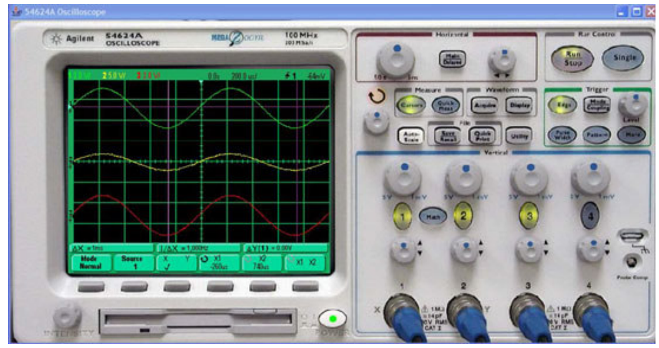

Figure 4. Larger interactive image of oscilloscope

Users are then able to interact with these instrument images, which includes animated controls and displays, in the same way that they would when physically operating the instruments. For example, the mouse is used to click on a button or rotate a knob in the same way that a finger would be used to press the button or turn the knob. The GUI presents the instruments with a sense of realism and functionality that matches the physical instruments.

The interactively realistic GUI gives students a sense of physically being in the laboratory, since the instruments they see and the tasks they perform are the same as those in a physical laboratory. All of the buttons on the GUI give a form of visual feedback, such as button illumination or depression of the button, to show the user that the button has been pressed or activated.

A JVC web camera, which has its own server, is also present in the remote laboratory. The camera provides live video streaming of the remote laboratory to the NetLab user. The camera is able to be controlled by the user through the use of the GUI. This includes zoom, pan and tilt functions that allow users to view the laboratory, as well as preset positions that focus on specific instruments. The camera can be used to view the equipment in the laboratory as well as monitor the execution of the user's commands on the instruments. The camera further enhances the user's feeling of being present in the laboratory. The live streaming is able to be switched off at any time to conserve bandwidth usage.

Multiple users are able to use NetLab at the same time, as long as they are all booked for the appropriate session time slot. Groups of up to three users can all be accessing and interacting with NetLab at the same time, as well as administrators who can access NetLab at any time.

The real physical laboratory is situated in the Sir Charles Todd Building, which is the house of the School of Electrical and Information Engineering at Mawson Lakes Campus of UniSA. Students or visitors access the remote laboratory via the Internet through the UniSA server where they are required to register first and to book their time slot to conduct an experiment. They obtain their password for the future login. The log-on information is recorded and once the information is accepted, the access is granted and students or visitors are directed to the laboratory site where they can conduct experiments. It can be done at any time from any location with the Internet access.

5. PROCESSES IN REAL AND REMOTE EXPERIMENTS

Work on experiments follows certain steps and procedures which may be similar or very different for real experiments and remote experiments. The following paragraphs are based on practical work procedure in real laboratories and the remote laboratory NetLab in the School of Electrical and Information Engineering at UniSA which may vary from other schools and universities.

Generally, students' laboratory work involves the following steps and procedures:

- Students' preparation for experiments
- Conducting experiments
- Analysis of results
- Submitting practical reports
- Assessment
- Evaluation and reflection

Collaborative learning can be encouraged during preparation, conduction and analysis of experiments, when students are asked to work as a team. This can be implemented for peer assessment, evaluation and reflection as well.

Students' preparation for experiments

For a real experiment students are required to perform a detailed preparation, possibly including required formulae, procedures and tables for recording measured results. Student preparation is checked at the beginning of the practical session, and sometimes assessed. Without preparation, students are often not allowed to conduct the experiment resulting in a zero mark for the experiment. In remote laboratories students also need to do a prescribed preparation but no one will check it. This leaves the responsibility on students. They can try to perform the experiment and if they are lost and have difficulties, which are reasonable to expect without proper preparation, they can log out and reattempt the experiment at later dates after doing the proper preparation until they successfully finish the experiment. In this sense the remote laboratories show the advantage as students need not only to do the prescribed preparation but to gain a full understanding of the experiment before they attempt it, because there is no supervisor in the laboratory to lead them through. Students are encouraged to do preparation as a team, as they can exchange ideas and proposals for conducting experiments, as are not supplied with detailed instructions for practical experiments. Responsibility for learning is fully left to the students, thus also enforcing students' centred learning [17].

Conducting experiments

Conducting the experiment itself is the crucial component of the whole laboratory process. In the real experimental session students are usually working in teams of 2-3 students. In our School a teacher usually supervises a class of 6 teams during a 2 hour laboratory session. In remote experiments students are also working in teams of up to 3 students, but there is no supervisor. This is a stage when students have to collaborate to conduct an experiment successfully.

During experiments students first connect the required circuit in order to obtain specific measurement results using available instruments and circuit components using the Circuit Builder[15]. Circuit Builder software has been developed for NetLab to allow students to connect real instruments and components remotely via the Internet. Students are also able to change values of circuit components. As can be seen from Figure 5 wiring using the Circuit Builder can be as messy as in a real laboratory. Circuit Builder uses photographic images of components and instruments in order to make wiring look as realistic as possible.

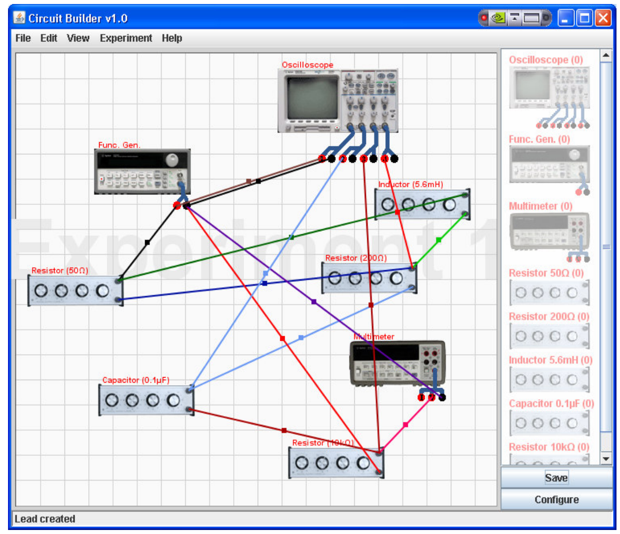

Figure 5. Example of the Circuit Builder wiring

The connection of right components in the right order requires theoretical knowledge as well as hands-on skills. Students also have to communicate efficiently to achieve required results as a team. Most of the available remote labs use prewired circuits. Thus the whole exercise lacks the typical stage of real experiments, where students are often lost in the messy heap of wires, instruments and components. This is one of the most important part of an experiment where students learn how to connect supply or measurement devices to obtain the proper responses and not to damage or destroy anything. This really requires the team work and proper collaboration among students.

Once the circuit is connected, the next stage of the experiment is to control the instruments and take measurements. This requires again collaborative work of the all team members. Most of the remote laboratories use a text based Graphical User Interface (GUI) for users to control devices which are not only unrealistic but also prevent students from learning to operate the real instruments.

Once students are satisfied with the measurement results, which can also be seen using the NetLab web camera, they can download data to their computer as they would do in the real experiment scenario in the laboratory.

Analysis of results

The next stage is nearly identical for real and remote experiments. Students are using saved data to produce the experiment report. They are often asked to carry out mathematical calculations and simulations and compare measured, calculated and simulated results. Students are encouraged to work as a team, to split tasks and/or to conduct same tasks and to compare results. If everything went smoothly they should obtain three very similar responses. If not, remote laboratory offers a superior advantage over the real laboratory. Normally, students do not have an opportunity to come back to the real laboratory and repeat the experiment. However, in remote laboratory they can easily book another time slot, which is what many students do even before they start the first session "just in case" to repeat the experiment or part of the experiment where they believe is a mistake.

Students' access to NetLab

When NetLab was just introduced in 2002, the majority of students conducted experiments in computer pools at UniSA campuses, where they could communicate and collaborate in person. Now, after five years, most of remote experiments are conducted "from home". Our recent survey revealed that out of 52 students participating in the survey only 2 did not have access to the Internet at home; 45 students had a broadband connection at home, which eliminated the difference between the access of the system from a UniSA campus and the access from home. Conducting experiments via the Internet requires online collaboration.

Evaluation and reflextion

Every year students are asked to submit a critical evaluation of NetLab, which is used for its continuous improvements. The improvements do not only include hardware and software development and the support material, but also the ways in which students collaborate in remote laboratory. As students asked for a better communication tool in remote laboratory, the incorporation of the telecommunication among students conducting experiments, is now under consideration. The implementation of web cameras into new laptops is making the telecommunication task possible in the near future.

However, our first impression is that students learning outcomes are much better in remote laboratories than in real laboratories. The last year, for the first time students had to use NetLab to perform all experiments in the course Electrical Circuit Theory. This is the first year course run in the second half of the academic year. These students already had experience, although not extensive, in using basic electrical engineering instruments while working in real laboratory during the first half of the year. They were required to work on experiments in their own time as teams and submit a cumulative report for all experiments at the end of the study period.

Their reports show clearly the superior learning benefits from this mode of laboratory work when compared to learning outcomes of previous generations of students who worked in a supervised real laboratory during the scheduled classes. Despite the occasional technical difficulties with remote access these students repeated experiments whenever they found differences between measured, calculated and simulated results if they suspected there may have been an error in the experiment. They also spend more time checking their calculation and thus learning the theory. They also often repeated the simulations. Consequently they developed better knowledge base, better analytical skills and also better collaborative skills, which was reflected in their laboratory reports.

6. CONCLUSION

It is evident from students' responses that they realised they had learned essential skills during the remote experiments skills, which they will need when they go to work in the present "real world", where online collaboration, consultation and team work is required. Moreover, it is the belief of the authors that if the current level of remote experiment development continues, it will ultimately lead it to be becoming the preferred method of learning for future graduates.

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