Enriching student learning experiences in remote laboratories

Z. Nedic, J. Machotka & A. Nafalski

University of South Australia
Adelaide, Australia

Opening Address

ABSTRACT: Currently, learning international collaborative skills are not part of engineering curricula. However, with the increasingly globalised world, it is expected that future engineering graduates will work in internationaly distributed teams. Consequently, the engineering industry will soon require engineering graduates to be prepared for work in this new environment. In this paper, a framework developed for teaching students international collaborative skills through international on-line collaboration in remote laboratories is presented. Remote laboratories allow students to perform experiments on real equipment remotely via the Internet. In early 2000, a remote laboratory known as NetLab was developed at the University of South Australia. It was intentionally developed as a collaborative environment in order to emulate students' collaborative work in a real laboratory. As such, it also provided a unique opportunity for Australian students to collaborate with students from other countries and for the educators to develop a framework to support teaching students' international collaborative skills.

INTRODUCTION

Practical skills are important attributes of every engineering graduate. The Internet has provided tertiary education with the opportunity to develop innovative learning environments. The teaching and learning of practical skills has gained a new dimension with the emergence of remote laboratories. Remote laboratories allow students to perform experiments on real equipment remotely via the Internet. The rapidly growing number of remote laboratories (RLs) worldwide is the evidence that the educational community has recognised their potential to develop into a creative, flexible, engaging, and student-centred learning environment. Even a brief review of the existing RLs shows considerable diversity in their structure, design and implementation. However, their real potential is yet to be discovered. As a part of a global worldwide computer network they can be accessed at anytime from anywhere by anyone and, therefore, can easily be shared among partner institutions.

Recently, there has been a strong tendency among universities to share their RLs on the global computer network. This creates an opportunity for students to access a variety of equipment and experiments giving them previously unprecedented learning opportunities. Furthermore, RLs offer students an opportunity to collaborate with students from other countries and enrich their cultural experience and on-line collaboration skills. As a computer supported learning environment RLs can be integrated with virtual learning tools.

In this paper, a framework for teaching international on-line collaboration skills in the NetLab remote laboratory at the University of South Australia (UniSA) is presented [5].This framework was developed as part of the project supported by an Australian Learning and Teaching Council (ALTC) competitive grant.

OVERVIEW OF PREVIOUS WORK

In the past decade, an increasing number of remote laboratories has been developed worldwide [1]. However, most of the remote laboratories are developed as single user environments and do not support collaborative work. This is surprising as students in real laboratories commonly work in groups and, as a consequence, they develop collaborative skills and appreciation for team work as an important graduate attribute highly valued by engineering industry. On the other hand, it is not surprising as the development of a collaborative remote laboratory requires extensive work by highly skilled software developers.

In earlier publications, the work on the development of the UniSA's NetLab remote laboratory as an interactive on-line learning environment was described [2-9][13]. Few other RLs exist that support synchronous collaboration for physically distant students [10-12]. This uniquiness of NetLab gave an opportunity to integrate international on-line collaboration skills into the engineering curriculum of some courses. For this purpose, it was needed to develop a framework aimed at preparing students for these activities before they engage in on-line collaboration in order to maximise the prospects of the successful experience.

Although students regularly collaborate in conventional laboratories on experiments and on projects, it is commonly assumed they know how to collaborate. However, the majority of students see this collaboration as an opportunity to share the work in order to reduce the workload for each student in the group. This approach certainly reduces the learning opportunities for students and may even be counterproductive, if a student does not engage with all aspects of the experiment/project, but rather learns only *his/her own part*.

Obviously, there is a need to teach students how to collaborate, before they are being taught how to collaborate internationally. This requires teaching students the purpose of the collaboration including international collaboration. However, one should be aware that engineering students prefer to focus on learning technical skills rather than soft skills. Consequently, a good framework should focus on integrating these two types of skills rather than treating them separately.

FRAMEWORK

The framework for international collaboration in remote laboratories addresses three general aspects that affect this collaboration, as shown in Figure 1:

1. Discipline Knowledge (DK);
2. Enabling Technology (ET), and;
3. Cultural Intelligence (CI), also referred to as cultural capability and quantitatively expressed by Cultural intelligence Quotient (CQ) [14].

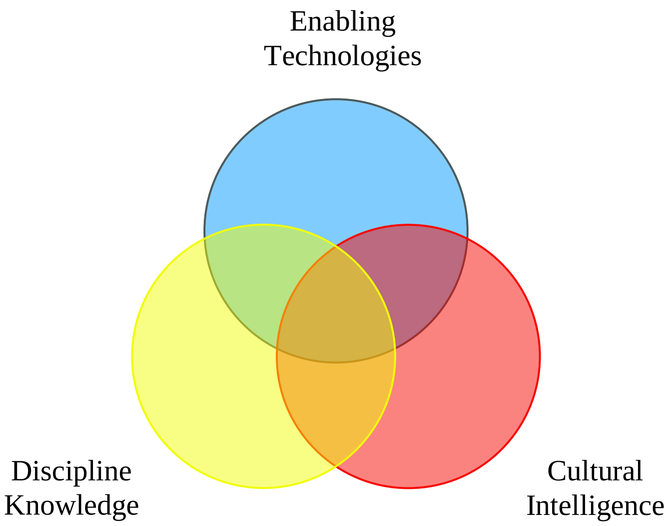

Figure 1: Aspects affecting international on-line collaboration.

Discipline Knowledge (DK)

Students collaborating on an experiment will not have identical discipline knowledge and skills as the students may be in different stages of their programmes or the programmes may not be identical in different countries. So lecturers should be very modest in their expectations of the students' discipline knowledge, otherwise the on-line collaboration experience might not be successful. To address this issue, it is recommend that the experiment instruction hand-outs should include as much detail as possible of the necessary, or assumed discipline knowledge, and should include references to material, which students can use to update their skills and fill in gaps in their knowledge.

However, the instruction handout should not look like a *cookbook*, but should include collaborative learning tasks in a form of topics and problems for discussion in order to initiate interaction between students. Including these discussion tasks is a vital part of the process, and lecturers need to be aware of this and be equipped with skills to create them well.

It also helps if one of the discipline fundamental courses is selected for this collaboration rather than more advanced courses. This will increase the probability that students will have the required discipline knowledge as more advanced courses and more diversity between programmes could be expected. The concept is universal and can be implemented in any course or programme as long as the students are enrolled in the same discipline. However, it will depend a lot on the effort and creativity that a lecturer puts in to support student activities.

In this project, two courses, a 2nd year course Electrical Circuit Theory and a 3rd year course Signals and Systems, were used. Both courses are common fundamental courses for all electrical engineering disciplines including computer systems engineering.

Enabling Technologies (ET)

Technology is in a constant developmental process. International on-line collaboration very much depends on the development of the Internet and its constantly growing and improving software applications. The important technologies related to this project are on-line communication environments. It is also important that students develop proficiency in using them. On campus students find it more convenient to collaborate in a face-to-face environment and, consequently, they might not have developed the skills required to use on-line communication applications such as Skype.

In this framework, FlashComs video communication software shown in Figure 2 was adopted, which can be used free of charge. This software and its interface are user friendly. It provides a *whiteboard*, although one with very basic drawing tools as also shown in Figure 2, which students can use to draw diagrams, such as electrical circuit diagrams.

This is an important feature as there is often a need for students to discuss problems related to the circuits, and being able to draw a diagram makes the discussion much easier. The FlashComs video communication is integrated with NetLab and can be started within the NetLab client. However, the NetLab has its own provision for chat communication if students only require a quick/simple communication or would like to save on bandwidth in cases in which the connection is slow. The NetLab GUI with its own chat window in the bottom left-hand corner is shown in Figure 3.

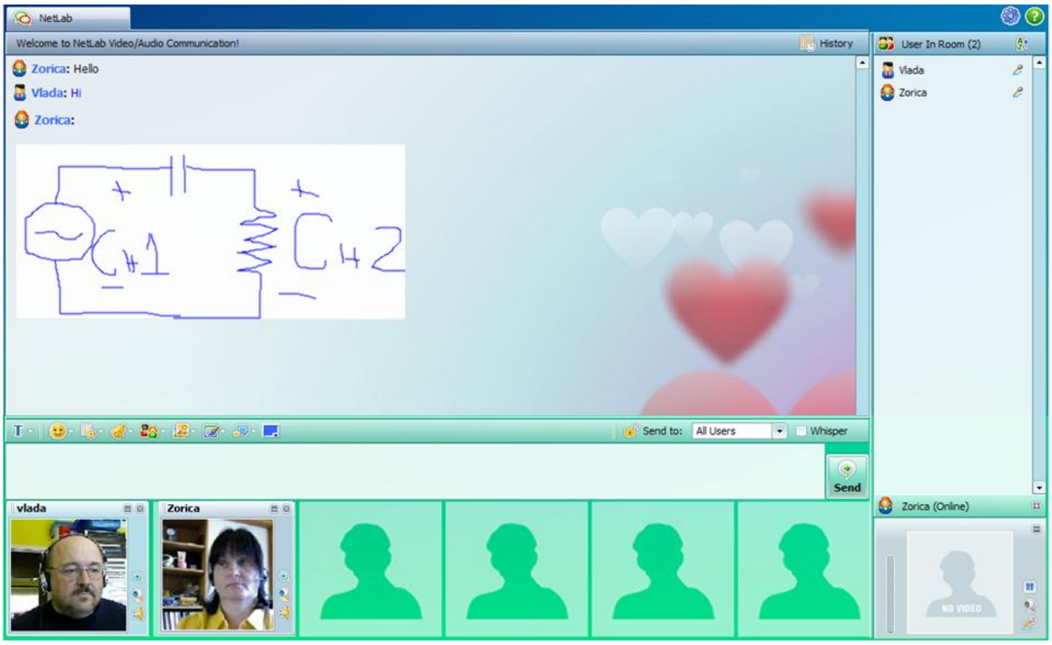

Figure 2: FlashComs software was used for video communication.

From its very first conceptual design, NetLab was envisaged as a collaborative RL [15]. To support the collaborative concept a complex management system needed to be developed. Apart from the provision for communication, it required a sophisticated booking system that would allow a number of students, later restricted to maximum of three, to book the same time slot. Also, as it was anticipated that students might not be in the same time zone, the booking system shows each user the booking times in his/her own time zone. The booking system shows the user name when the mouse is positioned on a booked slot, so students can see and select their collaborating partners.

An even more complex feature of the NetLab software, written in the Java programming language, is provision for all logged-on users to have a full control over the system. Every student can control the function of all equipment and, thus, all students can participate equally in the laboratory experiment. The users control instruments by pressing buttons and turning knobs on the animated instruments' of GUI shown in Figure 3. The NetLab software uses the queuing system for commands from all users, but also monitors the actions of all users and eliminates users' commands that are considered redundant. This feature is done in such a way that users do not notice the system intervention. On the other hand, this feature reduces the number of commands in the queue and makes NetLab's operation more responsive to users' actions.

With the features described above, the UniSA RL NetLab is a comprehensive collaborative environment that supports students in the development of their international collaboration skills. However, depending on the given collaborative task, students might need to use other Internet applications, such as GoogleDocs and Wikis. In an example below, it is shown how students enrich their skills through collaboration with students outside their usual social networks as they learn to use new software from their international collaborative group members.

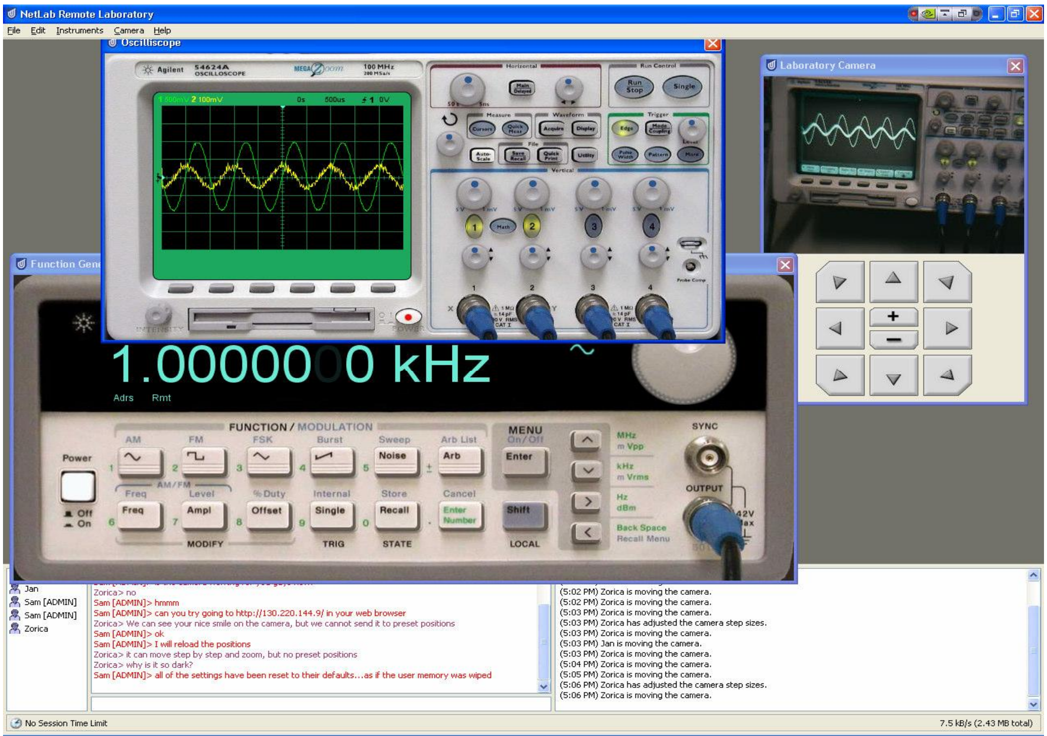

Figure 3: NetLab GUI with its own chat communication screen in the bottom left-hand corner (adapted from [16]).

Cultural Intelligence (CI)

In the same way that the IQ is an indicator of a person's intelligence, the CQ is an indicator of his or her cultural intelligence. In the following paragraph Earley and Mosakowski in [14] describe the meaning of cultural intelligence:

> *…culture is so powerful it can affect how even a lowly insect is perceived. So it should come as no surprise that the human actions, gestures, and speech patterns a person encounters in a foreign business setting are subject to an even wider range of interpretations, including ones that can make misunderstandings likely and cooperation impossible. But occasionally an outsider has a seemingly natural ability to interpret someone's unfamiliar and ambiguous gestures in just the way that person's compatriots and colleagues would, even to mirror them. We call that cultural intelligence or CQ. In a world where crossing boundaries is routine, CQ becomes a vitally important aptitude and skill…*

In today's university environment, students working in groups will unavoidably have to work with members from different cultural backgrounds. In order to solve the common task, they will co-construct a common language, which is not aimed at perfect mutual understanding. Students collaborating on-line are restricted in the time they can spend communicating with students from different countries. Consequently, they will try to develop just enough mutual understanding to solve the given task, rather than developing mutual understanding about everything. Thus, the cultural interactions become more functional in nature rather than being of a traditional nature [17].

The analysis of the initial trials involving volunteering students confirmed that students spend minimal or almost no time learning even basic facts about other cultures [3]. This certainly limits students' opportunities to broaden their cultural experience and take the full advantage of the international collaboration with students from different countries. This prompted the intervention in the follow-up trials. The intervention included requiring students to find out a number of facts about their collaborating partners, their countries, and programmes and courses they study. The questions and some of the answers are shown in the next section.

EXPERIENCES FROM TRIALS

The first trials involved 3rd year students enrolled in the Signals and Systems course. The students from Australia collaborated with students from Singapore on an experiment that required investigation of the 3rd order circuit. The experience from this trial demonstrated that the students showed very little or no explicit interest in other students' cultures. In the follow-up trial, which involved collaboration of students from Australia with students from Sweden, questions were included that would initiate discussions about cultural diversity and, hopefully, encourage students' broader cultural curiosity. Table 1 includes a list of some questions and answers to illustrate this attempt.

Table 1: Questions that encourage cultural curiosity.

Responses by Australian students	Responses by Swedish students
Q1. What have you learnt about the foreign country from this collaborative exercise?	
In Sweden they have polar bears that are dangerous. They like to eat them :) They are 7.5 hours behind us and they have cool accents. They have to learn 3 languages before they leave school and they have an excellent sense of humour.	They have small bears that fall out of trees then they eat them for lunch ;) Koala bears sleep for 19 hrs a day. The only time people from Australia aren't watching out for koalas is when they go shark diving...
Q2. What have you learned about programs that your colleagues from foreign countries are doing (include differences and similarities)?	
They have to learn programming languages too… Lucky b (we swear a lot down here :)) – MATLAB……..! - can be a very frustrating program to use :D, …	Matlab is a part of the toolbox in the course, for our course we can use it if we have it but its not necessary nice to be a Lucky b ;) => graph is a very good program that gives us a lot (recommend)… Link to the Web page for Graph 4.3 (http://www.padowan.dk/graph/) the Web page is even in English :-).
Q3.What have you learned about the course that your colleagues from foreign countries are doing (include differences and similarities in structure of the course, theory approach, simulation software used, etc)?	
We second that :)	Only familiar with this lab and it seems quite similar in the approach and theoretical prep.
Q4. What is your perception of foreign partners' knowledge background (i.e. is it at a similar level as yours, if not, is it higher or lower, or in some area higher and in other lower)?	
…although you guys are much better at dealing with graphs than some of us here :)	Impossible to know after a few hours but its like in all courses we all have specialities and it would be better to be prepared for that before the experiment. In that way we could divide the task between us to get the exp more efficient.
Q5. Comment on cultural and behavioural differences that you have observed.	
I haven't noticed any ... other than accents - especially ours (the Australian accent is the worst on the planet I reckon :)) We dive with sharks - you eat polar bears :) what's different :)	we are all human and not that different and its always nice to see that it works :) I quite like your accent its comfortable
Q6. Do you think that you have enriched your collaborative learning by using different practices and knowledge?	
Absolutely but the importance of planning the experiment and preparing the conditions in advance is a critical point. We use the BTH labb… in a way like yours but we have for example a breadboard that we place components on. It's not java based	Yes - it would have been much more helpful to you guys if you had the NetLab info last week and we had a less laggy way of utilising laboratory environments….if we could have just used NetLab itself instead of ShareApps we all could have participated more in the actual prac. What is the laboratory environment that you guys use and how do you find it?
Q7. List what you consider as desirable attributes of an international group member.	
A GOOD SENSE OF HUMOUR - we had a GREAT time :)	Humour is a tool the best one :) if all are prepared and the experiment are well coordinated in time and what tools we are supposed to use => well its just a matter of communication skills to get the job done

CONCLUSIONS

It is not clear to the authors why students do not naturally show more interest in other cultures; maybe engineering students are too focused on technical issues and feel outside their *comfort zone*, when involved in cultural interactions. To find answers to this would need a more thorough investigation of the topic. However, this also shows a clear need to involve students in international collaborative activities to gain confidence in intercultural communication as their future career may very much benefit from this experience.

In this paper, it was shown how the framework developed as part of an ALTC project addresses the three main aspects of international collaboration of students in remote laboratories. However, it was realised that students' interactions cannot be fully controlled. It has to be accepted that sometimes it will not be *perfect* and that students can only be encouraged to embark on this activity and be provided support to make the experience more successful and enjoyable.

ACKNOWLEDGEMENTS

Support for this publication has been provided by the Australian Learning and Teaching Council Ltd., an initiative of the Australian Government, Department of Education, Employment and Workplace Relations. The views expressed in this publication do not necessarily reflect the views of the Australian Learning and Teaching Council. The authors also wish to thank all students that contributed to the NetLab development and those who participated in this project.

REFERENCES

1. Gröber, S., Vetter, M., Eckert, B. and Jodl, H.-J., Experimenting from a Distance - Remotely Controlled Laboratory (RCL). *European Journal of Physics*, 28, **3**, S127-S141 (2007).
2. Nedic, Z., Machotka, J. and Yordanova, S., Collaboration in remote controlled laboratory. *Proc. 14th Scientific Symposium with International Participation - Metrology and Metrology Assurance,* Sozopol, Bulgaria, 60-64 (2004).
3. Machotka, J. and Nedic, Z., Collaboration in remote laboratory – vision for the future. *Proc. 6th Inter. Conf. on Engng. Educ., Education '09, part of the 13th WSEAS Multiconference on Circuits, Systems, Communications and Computers (CSCC 09)*, Rhodes Island, Greece, 80-84 (2009).
4. Machotka, J., Nedic, Z., Nafalski, A. and Göl, Ö., A remote laboratory for collaborative experiments. *Proc. 2009 ASEE 116th Annual Conference and Exposition,* Austin, TX, 15 (2009).
5. Machotka, J., Nedić, Z., Nafalski, A. and Göl, Ö., Collaboration in the Remote Laboratory NetLab. *Proc. 1st WIETE Annual Conf. on Engng. and Technol. Educ.*, Pattaya, Thailand, 34-39 (2010).
6. Nafalski, A., Machotka, J., Nedic, Z., Göl, Ö., Scarino, A., Crichton, J., Gustavsson, I., Ferreira, J.M., Lowe, D. and Murray, S., Collaborative learning in engineering remote laboratories. *Proc. International Conf. on Remote Engng. and Virtual Instrumentation REV 2009*, Bridgeport, CT, USA, 242-245 (2009).
7. Machotka, J., Nedic, Z. and Mohtar, A., Can remote laboratories offer collaborative learning environment? *Proc. 2008 Inter. Conf. on Frontiers in Educ.: Computer Science and Computer Engng*., Las Vegas, Nevada, USA, (2008).
8. Nafalski, A., Nedić, Z., Machotka, J., Göl, Ö., Ferreira, J.M.M. and Gustavsson, I., Student and staff experiences with international collaboration in the Remote Laboratory NetLab. *Proc. 1st WIETE Annual Conf. on Engng. and Technol. Educ.*, Pattaya, Thailand, 40-45 (2010).
9. Nedic, Z. and Machotka, J., Remote Laboratory NetLab for effective teaching of 1st year engineering students. *i-JOE Inter. J. of Online Engng*., Kassel University Press, **3**, 6 (2007).
10. Gravier, C., Fayolle, J. and Bayard, B., Coping with collaborative and competitive episodes within collaborative remote laboratories. *Proc. Inter. Conf. on Remote Engng. and Virtual Instrumentation REV'08,* Düsseldorf, Germany, CD (2008).
11. Callaghan, M.J., Harkin, J., McColgan, E., McGinnity, T.M. and Maguire, L.P., Client-server architecture for collaborative remote experimentation. *J. of Network and Computer Applications*, 30, **4**, 1295-1308 (2007).
12. Ferreira, J.M. and Mueller, D., The MARVEL EU project: A social constructivist approach to remote experimentation. *Proc. 1st Inter. Symposium on Remote Engng. and Virtual Instrumentation REV'04* Villach, Austria, 11 (2004).
13. Nedic, Z., Machotka, J. and Nafalski, A., Remote laboratories versus virtual and real laboratories. *Proc. 33rd ASEE/IEEE Frontiers in Educ. Conf*., Boulder, Colorado, USA, T3E1-T3E6 (2003).
14. Earley, P.C. and Mosakowski, E., Cultural intelligence. *Harvard Business Review*, 82, **10**, 139-146 (2004).
15. Machotka, J. and Nedic, Z., Online Remote Laboratory (Netlab). *Proc. 5th UICEE Annual Conf. on Engng. Educ.*, Chennai, India, 179-183 (2002).
16. Machotka, J., Nedic, Z. and Göl, Ö., Collaborative learning in the Remote Laboratory NetLab. *J. on Systemics, Cybernetics and Informatics (JSCI)*, 6, **3**, 22-27 (2008).
17. Clark, H.H. and Brennan, S.E., *Grounding in Communication*. In: Resnick, L.B., Levine, J.M. and Teasley, S.D. (Eds), Perspectives on Socially Shared Cognition. Washington, DC, US: American Psychological Association, 127-149 (1991).