Remote laboratories in Engineering Education: Trends in Students’ Perceptions

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***Abstract**: Remotely accessible laboratories are an increasingly popular innovation in engineering education. Since 2001, The University of Technology, Sydney has implemented a number of remotely accessible laboratories. This paper presents an analysis of students’ feedback responses to their use of the laboratories. The responses show that students not only appreciate the flexibility of the remote access option, but also that they feel that the remote option encourages them to take a deep learning approach to the material.*

Introduction

Remote laboratories allow students to conduct practical laboratory exercises with real equipment without being physically present in a conventional laboratory. This is different to simulated laboratories that do not use real equipment. The flexibility that comes with twenty four hour seven days a week access to remote laboratories has the possibility to change teaching and learning in the ways of practical assignment/project design; students’ opportunities to do more practice/additional experiments to help reinforce concepts and provide further understanding; access to state-of-the-art equipment; more effective lab management, etc.

In June 2001, the Faculty of Engineering at the University of Technology, Sydney (UTS), decided to pursue a strategic focus directed toward developing remotely accessible laboratories for undergraduate engineering courses. Five remote laboratories have been developed and used in various undergraduate subjects (Lasky et al. 2005; McIntyre et al. 2006).

When moving to a new teaching approach, it is important to ensure that this approach still leads to the required learning outcomes for the students. In order to assess whether these remote labs are adequate for student learning, three surveys were conducted in the Autumn and Spring semesters in 2006. This paper presents the survey instrument, analyses student feedback, and summarises student comments to show their perceptions not only of their access to the hardware, but also of their learning within the remote laboratory context. Section 2 in this paper briefly introduces the two remote laboratories. Section 3 covers the numerical data gathered by the surveys, and section 4 deals with the open-ended responses of the students. The last section is conclusion and remarks.

The UTS remote PLC and water-level control labs

This paper deals with two of the UTS remote laboratories – the Programmable Logic Controller (PLC) laboratory, and the water level laboratory. These laboratories are designed for mechanical and mechatronic engineering students, and have been used in the teaching of subjects “Advanced Manufacturing”, “Dynamics and Control” and “Mechatronics 2” since 2006.

The Remotely Accessible PLC Laboratory

There are six PLC test rigs with each consisting of two electro-pneumatic cylinders, two valves, one Allen-Bradley PLC (MicroLogix 1200) and NetENI Ethernet module (Figure 1). Two reed sensors are installed in each cylinder to measure the piston position. One camera and a microphone are used to take the video and sense the sound of piston movement, respectively. The NetENI module is connected to both the PLC and a private PLC Ethernet network. The rig is monitored by an Apple iSight™ firewire webcam, providing video and a Macmice Micflex™ USB microphone providing audio. These are connected to the server (Lasky et al. 2005). Ladder logic diagrams can be developed in the RSLogix programming environment and then downloaded to the PLC for controlling the movement of the two pistons.

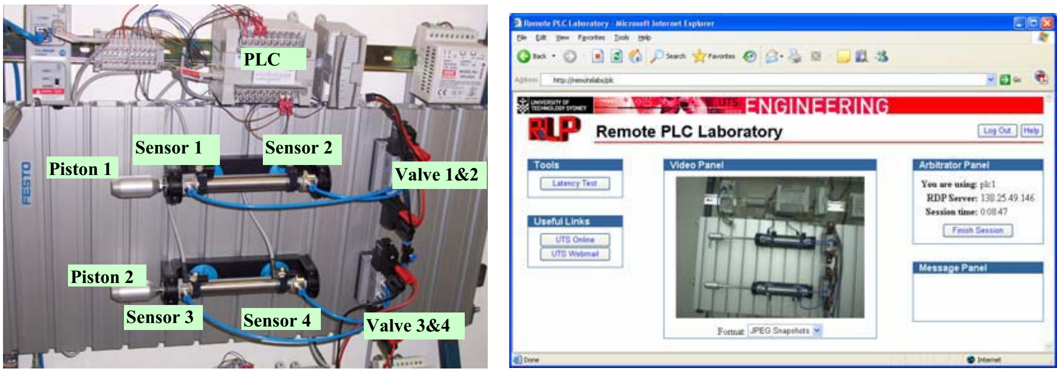


Figure 1: (a) Remote PLC lab and (b) User interface (Lasky 2005)

This remote lab allows students to write programs for PLC to interact with pneumatically driven cylinder apparatus. Students can view streaming video over the Internet, which provides them with visual feedback on the effectiveness of their programming.

The Remotely Accessible Water-Level Control Laboratory

The coupled tank apparatus, purchased from Kent Ridge Instruments, consists of two tanks, two pumps, two level sensors and a reservoir as shown in Fig.2. The two tanks are connected together via a small opening at the bottom of the tanks. Water flows into the top of the first tank, and into the second tank via the small opening. The water then flows out of the second tank and into a reservoir via a valve at the bottom of the tank. The two pumps and two levels sensors on the coupled tank apparatus are connected to the analogue voltage outputs and inputs of a LabJack data acquisition board. Two cameras and a microphone are used to provide visual and audio feedback. The user can access this via the Remote Laboratory webpage, where they can watch the live feed using Windows Media Player or Apple’s QuickTime player. For low bandwidth connection users have the option of viewing static JPEG snapshots that can be refreshed by clicking the image with their mouse. Audio feedback is provided using a MacMice MicFlex microphone (McIntyre et al. 2006).

In this laboratory, a computer-based control system can be developed and tested by the students which manages the water levels in two coupled tanks that are fed by water pumps. Again, the students observe real-time video and audio signals over the Internet which provides feedback.

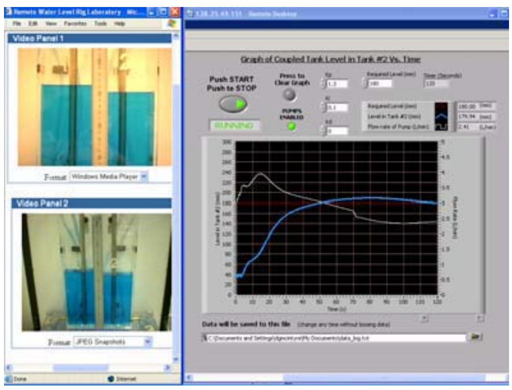

(a)

(b)

Figure 2: (a) Remote water-level control lab and (b) User interface (McIntyre et al. 2006)

Quantitative Responses

The remote PLC lab and the remote water-level control lab were used in 2006 Autumn and Spring semesters. The students were asked to respond to each of the following questions, using a 1-10 scale: 1= very poor/strongly disagree, 2-4 = poor/disagree, 5 = Neutral, 6-9 = good/agree, 10 = very good/strongly agree:

1. How do you rate the overall performance of the remote PLC lab?
2. Is it easy to use the user interface?
3. Did you find it easy to open and view the live video feed?
4. Didn’t you feel a degree of isolation between the physical system and you?
5. Did the information provided in the User Guide allow you to easily set up and run the experiment?
6. "While you were using the remote PLC lab, did you feel like you were operating real equipment?"
7. Did the remote PLC lab help you understand the practical aspects of PLC control system?
8. Did the ability to spend extra time on the experiment allow you to re-enforce the concepts learnt in class (imagine you have ten minutes only for the experiment if you physically do the experiment in the real lab)?
9. Did the ability to spend extra time conducting additional experiments allow you to further your understanding of PLC control and programming (imagine you have ten minutes only for the experiment if you physically do the experiment in the real lab)?
10. Did the flexibility of the remote PLC lab allow you to fit the laboratory work into your schedule
11. "Based on your experience using the remote PLC lab, do you prefer to use the remote lab in the future?"
12. Do you suggest us to develop more remote labs?
13. Do you think the UTSOnline discussion board helps in solving your problems while you are using the remote PLC lab?
14. Does the user guide provide sufficient information you need for the experiment?

Student responses to Questions 1 to 14 after they used the two remote labs (PLC: remote PLC lab and WLC: remote Water Level Control lab) are shown in Figure 3. It can be seen that student feedback is overall positive to all the 14 questions with many of them ranked over 8 out of 10. The responses to Questions 4 and 13 are not as good as those to other questions. Students feel a degree of isolation between the physical system, and that UTSOnline discussion board does not help very well in solving your problems while they are using the remote labs. Students would like to get their questions answered immediately.

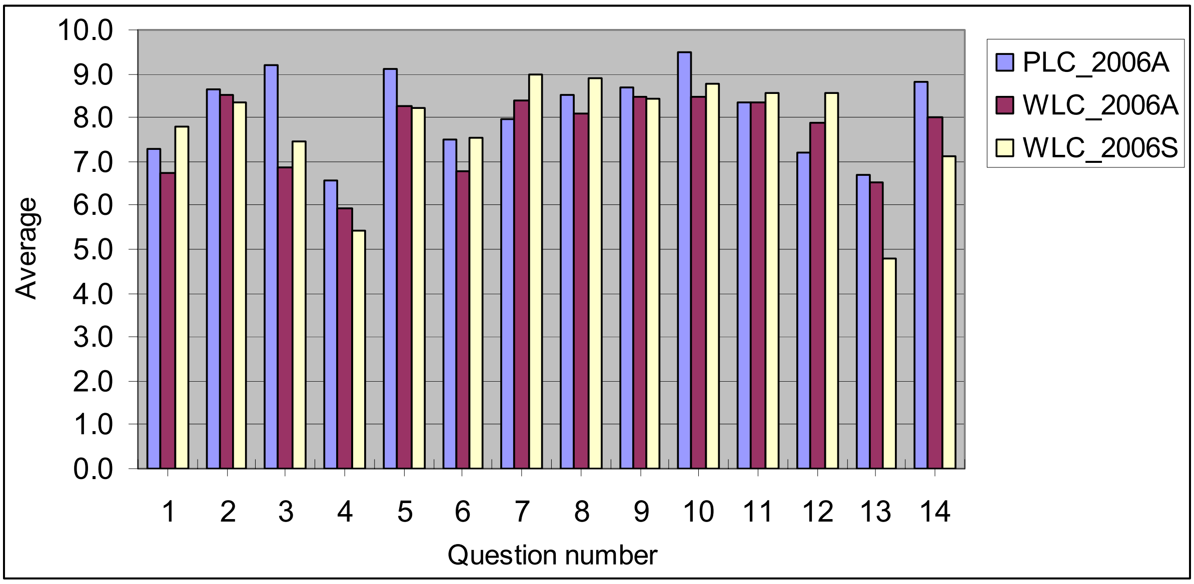


Figure 3: Student survey

Figure 3 shows that there is agreement to most of the questions. The flexibility-related questions as well as the pedagogically-related questions consistently show average agreement values of 7 or higher. This shows that students value the flexibility, but they also feel that the remote implementation is supporting their learning.

Qualitative Feedback

In order to provide scope for more rich feedback, and to promote the students' reflection about their own learning, students, who used the remote PLC lab in Autumn 2006, were also asked the following open ended questions:

1. What did you like about the remote PLC lab?
2. Suggested Improvements?
3. How do you feel that the remote PLC lab affected your learning outcomes for the subject (imagine you have ten minutes only for the experiment if you physically do the experiment in the real lab)?
4. How did the remote lab change the way you learnt compared to conventional laboratories?
5. What problems with the remote lab did you experience while using the remote PLC lab?

There were a wide range of responses to these open-ended questions, but some definite themes emerged.

Flexibility of Access

The flexibility themes were strongly represented, with 77 % of students explicitly mentioning some aspect of flexibility as a positive. The responses emphasised asynchronous scheduling:

"It made a great difference I like being able to spend time to do the experiment in my own time"

There was also an emphasis on the ability to take longer to complete the laboratory:

"Allowed more time to understand without the pressure of having to take it all in."

This appreciation of the flexibility was tempered by frustrations with the remote interface. Students had many comments on the interface as a negative – the desktop should have been configured better, there were problems with video lag etc. These responses are consistent with transparency statements from elsewhere (Givens and McShea 2000; Lindsay and Good Submitted).

There was, however, one counter example suggesting that the transparency isn’t necessarily perceived as critical for the students’ learning:

Although the remote lab didn’t feel as ‘real’ as the actual lab, (I couldn’t get the live video to work) I didn’t care about this. Its benefits in flexibility far outweighed this, and the remote lab gives the same results anyway

Nature of the Learning Experience

The students also commented on a range of pedagogical issues, which shows an awareness of the changed nature of the learning experience. The social context of the laboratory appeared in a number of the responses, with students commenting on the lack of a laboratory demonstrator, or their colleagues:

“The only thing was the lack of interaction with lab assistants which is always interesting to talk to someone who works with the equipment.”

“Can not discuss with others, can’t make sure on the right track or not so have to compare answer with others.”

“A negative would be the fact that there is no lecture supervision, preventing me from asking more questions as they came to mind during the experiment. I believe such a lab should be used after a demonstration in a real lab to allow students to communicate personally with the lecturer.”

The absence of the social context is one of the key challenges facing the development of remote laboratories, and the move from group work to individual work has significant consequences for the nature of the learning (Lindsay et al. 2007). Not all students were upset at the loss of the social context, however – one self-directed learner had this to say:

“*Was able to spend more time experimenting for myself rather than listening to an expert tell us what would happen.”*

Approach to the Lab

Student responses indicate that they had taken a changed approach to the lab – that they were engaging differently with the learning experience. In particular, they seemed to show a more reflective approach to their learning:

“In conventional labs you pretty much write down the results and think about what actually happened afterwards. With the remote lab you watch the first result, and then alter your settings depending on what your outcome is. It makes it a lot easier to clarify a misunderstanding of the theory”

“it was possible to test hunches and just generally much around with the equipment and see what happened.”

In addition to the remote access changing the way in which students go about tasks that they could otherwise perform in a hands-on laboratory, one student also identified a possible paradigm shift in the laboratory. The remote access mode is inherently computer-mediated, which provides new options for the recording of information:

“It was easy to type up the report as I go, instead of waiting till the experiment was finished, then forget what happened, and then try to write up a report from my notes.”

The remote access mode is offering new options to the students – options that either were previously unavailable to them, or options that they had previously not chosen to take.

Move to deeper understanding

Perhaps the most pleasing theme to emerge from the students responses was an apparent shift towards deeper learning outcomes. A number of students indicated that the remote access mode had encouraged them to learn more, rather than to just pass:

“Instead of only to achieve the subject outcome, we can further discover knowledge with time.”

"Gave more time to learn the concepts, was a more relaxed environment in which to learn and allowed the student to take responsibility for the undertaking of the laboratory."

"The lab lets you practice the experiment many times and compare the results in order to have a more fundamented idea."

Conclusion and remarks

Overall, the students respond positively to the remote laboratory implementations. A more fine grained analysis shows that this positive response extends across a number of aspects of the learning experience. Students appreciate more than just the flexibility of access – their appreciation is more than just a convenience. They see that the remote access mode transforms the learning experience, offering options (eg increased time, ease of recordkeeping) that are not available in a traditional hands-on on laboratory. They feel that these options have encouraged them to achieve deeper learning outcomes, and have improved the overall educational experience.

Acknowledgement

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