Student Feedback from the First National Sharing Trial of Remote Labs in Australia

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***Abstract* — In 2010, the Australian Labshare Project conducted a large-scale, nation-wide trial of remotely accessible laboratories, in which 6 universities and around 1,000 students participated. This paper summarises the motivation for this effort, introduces the trial participants and most importantly presents key topics from the subsequent extensive student evaluation survey. Directly from the student perspective, critical perceptions of remote labs are analysed and interpreted in the sharing context. The paper concludes with a number of recommendations for providers of remote lab infrastructure and for academics who wish to adopt remote labs in their coursework.**

***Index Terms* — Remote Laboratories, Resource Sharing, Student Feedback, Student Evaluation**

I. INTRODUCTION

It is a widely accepted opinion by engineering educators and prospective employers that practical, experimental laboratory classes are an integral and very important part of undergraduate engineering education. At the same time, funding and resources required to deliver high-quality pedagogic outcomes (equipment, maintenance, staffing, floorspace) are considerable and often overstretch available budgets. While universities are expected to provide modern facilities for their students and to deliver best pedagogic outcomes, many facilities are outdated, are believed to be underutilized or have limited accessibility, which applies especially to expensive and highly specialized equipment. The concept of remotely accessible laboratories ('remote labs') as valid supplements to existing hands-on facilities is gaining momentum around the world, but many educators still seek convincing evidence that remote labs can fulfil this promise in one way or another. Apart from financial and operational considerations, student feedback is a major contributor to decision-making processes in institutional adoption [1].

A. The Australian 'Labshare' Project

Formed in early 2009, the Australian Government-funded Labshare Project consists of the 5 member universities of the Australian Technology Network (ATN) [2] and is led by the University of Technology, Sydney (UTS). Labshare's goal is to create a nationally shared network of remote laboratories to address the issues of laboratory under-utilisation, accessibility, flexibility and foster the availability of high-quality experiments. Based on previously existing and newly developed equipment at its member institutions, Labshare currently provides access to more than a dozen types of so-called 'rigs' and over 50 individual apparatus, making it amongst the largest collection of its kind in the world. While the origin of these remote labs lies in a variety of engineering disciplines, development has recently also expanded into physics and health sciences. These remote labs are accessible 24/7 from anywhere over the internet and provide a diverse set of laboratory-based educational experiences to staff and students at Australian universities - more recently also to Australian high schools and ultimately, globally.

The primary aim of the Labshare project is to develop the technical, pedagogical and operational means to enable shared remote laboratory access. Along with other universities worldwide, remotely accessible laboratories have already existed at UTS since 2001 [3] and at the University of South Australia (UniSA) in Adelaide since around the same time [4]. In the formative stages they were predominantly used by their own engineering students. Since 2008, Curtin University of Technology (Perth) and UTS have regularly conducted cross-institutional sharing experiments of remote laboratories on a subject basis [5]. In order to build on this expertise, all LabShare ATN partners (including RMIT University in Melbourne and Queensland University of Technology in Brisbane) have since designed and constructed at least one remote experiment as part of the Labshare Project.

B. Laboratory Resource Sharing on a National Scale

The great number of existing and new experiments available through Labshare has enabled a very flexible approach to laboratory resource sharing across many engineering disciplines. The rig access and resource management software 'Sahara', which has been further advanced under the Labshare project, allows institutions to use a common sharing platform to provide access to their experiments without the need for proprietary client software. In its most recent release (v3.0, February 2011), Sahara supports the automatic allocation of individual rigs of the same kind (replications), queuing of users and a reservation system for bookings. This combination allows remote labs with relatively few individual rigs of one type (typically 3-5) to cater for over 100 students with little competition.

Sahara does not yet support group collaboration, unlike in [4], since the field of group formation and the most effective usage and access modes specifically for remote labs (collaboration vs. cooperation) are yet to be clearly evaluated and defined. Currently, student access takes place on an individual basis only, however the responsible academic can certainly allow or encourage group work in relation to the remote experiment by other means.

II. THE NATIONAL SHARING TRIAL

A. *Precursor: The National Survey into Laboratory Resource Sharing*

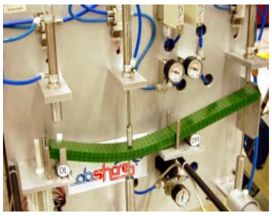
The 'National Survey into Laboratory Resource Sharing' was conducted between August 2009 and September 2010 [6], was designed to provide a factual basis and to capture a snapshot of the state of practical engineering education at all 34 Australian universities offering undergraduate engineering degrees. This extensive undertaking covered topics such as resourcing, pedagogic delivery, learning outcomes and organisational challenges and addressed all levels of responsibility, faculty/school executive, academic and technical staff. The review also investigated the potential of remotely accessible laboratories as a companion to hands-on facilities and the ways in which they can be used to improve students' learning opportunities and to address resourcing issues. The survey resulted in a comprehensive formal report, summarising methodology, participation and significant findings from the data collected [5]. Many of the survey participants were unaware of remote labs as an existing supplement to hands-on facilities, and follow-up on the interviews has since generated considerable interest at several universities.

One of the deliverables of the Labshare project is the demonstrated, successful sharing of resources between the ATN partner universities. Building on the expertise from internal use and during the previous trials between UTS and Curtin University, Labshare commenced the first *national* sharing trial in the second half of 2010. Due to the great interest from other institutions, invitations were also extended to a number of academics from non-ATN universities across several engineering disciplines. While the experiments at most ATN universities were nearing completion, the experiments formally used in this first trial were all located at UTS in Sydney.

B. *Remote Labs Experiments*

To illustrate the breadth of engineering disciplines involved in this first trial, a brief description of each apparatus employed shall be provided here, including an exemplary photo of the physical setup. All rigs feature at least one live video feed and a web interface for real-time interaction with the hardware. For more details on these experiments as well as other rigs available, the interested reader is referred to the Labshare catalogue of available experiments and lessons [7].

<u>Loaded Beam</u>

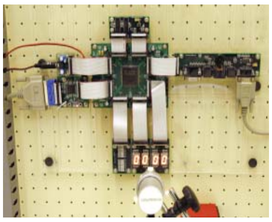


This rig is a small model of a structural beam. Students can interactively apply loads and load rates in different configurations to investigate the tensile and compressive forces in structures, such as concrete floors or aircraft wings.

<u>Coupled Tanks</u>

The rig is ideal for introducing students to the design, optimisation and application of common controllers, system modelling using static and transient measurements; steady state error analysis, transient response studies and controller tuning methods.

<u>Field-Programmable Gate Array (FPGA)</u>

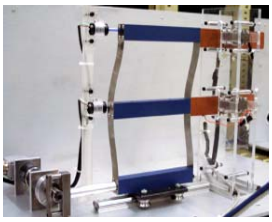


The rig consists of a Xilinx Spartan2E S2e300 board, allowing student to use VHDL tools to compose, upload and test their real-time implementations on a physical FPGA board.

<u>iRobot</u>

he iRobot rig is designed to allow students to explore teleoperation of robotic platforms, to employ and assess the accuracy of certain sensors and to implement various control algorithms, for example by navigating the iRobot inside a maze.

<u>Shake Table</u>

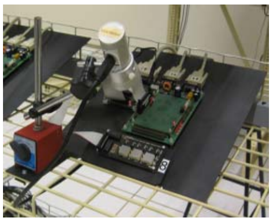


The shake table rig models the behaviour of a building during an earthquake. The rig uses a simplified structure to model a 2-storey building (2 degrees of freedom), and the earthquake tremor is simulated by linear base motion.

<u>PLC Automation</u>

The PLC laboratory consists of a set of Allen-Bradley PLCs. It is connected to a pair of pneumatically driven pistons, mimicking typical industrial applications. The PLCs are remotely programmed, giving students the opportunity to develop and test realistic automation designs using ladder logic.

Coldfire Microcontroller



The Coldfire rig allows students to practice their cross-development skills on a 32-bit microcontroller, using an open-source microcontroller-specific version of Linux.

C. Participating Universities

Between August and November 2010, six universities across five states, from both metropolitan and regional areas, formally participated in this trial:

- CQ University (Rockhampton/Gladstone)
- Griffith University (Gold Coast)
- Monash University (Melbourne)
- The University of Adelaide
- University of Tasmania (Hobart)
- University of Technology, Sydney

In the following list, the name of the subject, the number of students enrolled (in brackets) and the name of the Labshare remote experiment(s) are indicated for each participating class.

- Engineering Mechanics (257): Loaded Beam
- Process Control (110): Coupled Tanks
- Digital Systems (77): FPGA
- Advanced Digital Systems (43): FPGA
- Advanced Robotics (26): iRobot
- Dynamics&Control (66): Coupled Tanks, Shake Table
- Mechatronics 2 (40): PLC
- Real-time Operating Systems (12): Coldfire
- Advanced Dynamics and Vibration (22): Shake Table
- Engineering Investigation and Analysis (44): Loaded Beam

In addition to the classes listed here, several *informal* trials took place on prototypes at a number of ATN universities with recently developed experiments, bringing the approximate overall number of students involved in remote labs usage to just over 1,000.

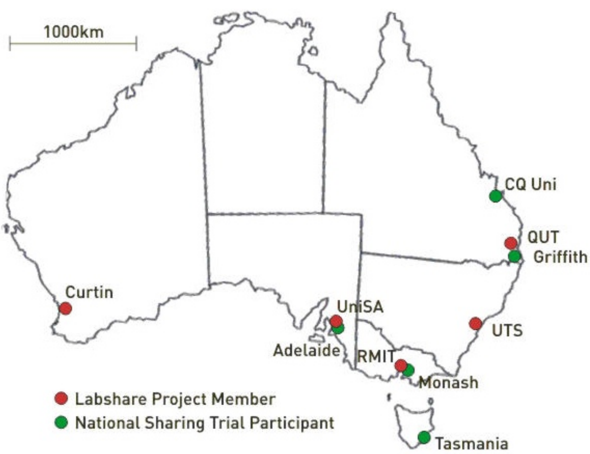


Figure 1. Geographic location of Australian ATN universities (Labshare Project universities) and other sharing trial participants

The geographic location of the 5 ATN universities (Labshare Project members) and the other 5 sharing trial participants is illustrated in Figure 1.

D. Access coordination

The requested access periods varied considerably between classes, from a two-week period to semester-long access on one rig type and to several four-week blocks on different rig types. In conjunction with the order of magnitude difference in student numbers, this resulted in a complex model of expected load of the rigs. Consequently, in order to avoid overloading at certain times and under-usage at other periods, intricate negotiation and coordination or these access periods had to take place between Labshare and the participating academics.

Simultaneous access of students from different classes to the same experiments was permitted at certain periods, however having assignment due-dates scheduled too closely together was generally avoided, as the remote labs tend to record the highest usage and waiting times[1] during the days immediately before the submission date ('just-in-time' delivery).

While Labshare had to control the access periods for operational reasons, all pedagogic aspects were entirely left to the specific academic. This included decisions about the integration of the remote experiment into the lesson structure, whether the experiment constituted an assessable subject component, was for 'extra credit' only or entirely optional. Quite obviously, these decisions also had a significant impact on the intensity of remote labs access by the students, as will be shown below.

E. Pedagogy

The practical use of remote laboratories in coursework is different from the use of hands-on laboratory sessions for a number of reasons, for example:

- Sensory interaction (tactile, aural, visual vs. visual only),
- Group work vs. individual work,
- Fixed time vs. flexible time,
- Availability of assistance vs. reliance on notes,

just to name a few. These considerations would normally flow into the pedagogic design of the practical laboratory lesson, including desired learning outcomes and methodology, which must be matched to the capability of the available laboratory equipment.

With respect to the sharing trial, all participating UTS academics had either contributed to the rig and lesson design themselves, or had repeatedly used the remote experiments in their subjects before. Existing material, such as user guides for remote lab rigs and sample lessons, were provided to the new trial participants for guidance, since they typically had no or little prior

[1] During the 2010 sharing trial, students were only allowed 'ad hoc' access. If all experiments were in use, they had to join a queue and wait for an experiment to become available. The current Sahara version 3.0 supports both ad-hoc queuing *and* reservations ('bookings').

experience with remote labs. In some cases, the material provided was extensively re-developed and adapted to the existing subject content, while in other cases the lessons were reportedly adopted with few changes.

All academics with remote labs experience chose to make the experiments part of an assessment task, and only 1 out of 5 ‘new’ academics decided to include remote labs just as an optional item. It will be shown below that these decisions had a major impact on the student experience and the achievement of learning outcomes.

Although the current implementation of the remote labs platform used in this trial does not yet specifically support simultaneous group collaboration from different locations, one of the academics decided to have the assignment completed *in pairs*, which had an interesting impact on the student feedback received.

Apart from administrative factors, such as user account access issues, or technical complications, such as video streaming, students were encouraged to interact directly with their lecturer or tutor as before; Labshare chose not to engage into assessment-related communication with students. As a result, a lot of these experiences remain with the academic at present. However, Labshare did encourage students to participate in an entirely optional and anonymous feedback survey after the completion of their access period, which is investigated in the following chapter.

III. Student Feedback Survey

A. Survey Design and Student Participation

In order to capture the remote labs experience of students across the country, Labshare designed a survey to collect both quantitative and qualitative data in 20 questions with respect to the following topics:

- Engineering disciplines and experiment used
- Frequency, time and place of usage
- Accessibility issues, such as waiting in a queue
- General experience with the concept of remote labs
- Collaboration and learning outcomes
- Comparison with hands-on labs
- Likes and dislikes
- Overall rating and opinion about future remote labs use in coursework

While the essential part of the questionnaire yields quantitative data, students were given many opportunities to qualify their answers or to leave comments. For practical reasons, the survey was implemented as an online version, which facilitated not only accessibility for the students (and therefore a higher response rate), but also subsequent analysis and reporting.

All students who were enrolled to use the remote labs rigs during the second semester in 2010 were invited both by their academic and by Labshare to complete this feedback survey. The invitation typically reached the students between 1 and 3 weeks after their submission date while their recollection of the experience was still fresh. It was clearly stated in the survey that participation was entirely optional, anonymous and had no impact on their assessment.

Access statistics from Sahara showed that out of the 697 students from the classes listed above, 540 *actually* accessed a rig at least once during the semester. Virtually all students who were not recorded (157) came from a single (large) class where participation was *optional*, and where only 42% of students chose to engage.

Overall, 171 separate survey responses were received up to the closing date on 10 Dec 2010. After manual quality control and consistency checks, 157 responses (91.8%) were deemed valid for further analysis, which is a very good rate for an online survey. Of those respondents, as many as 142 (90.4%) completed the entire survey – again, a very high rate. In conclusion, 27.4% of all students who actively participated in the trial also took the survey and left feedback, which can be deemed a sufficient sample size to represent the entire student cohort. It must be mentioned, however, that the participation rate per institution varied considerably and was not necessarily proportional to the participating student numbers, as depicted in Figure 2.

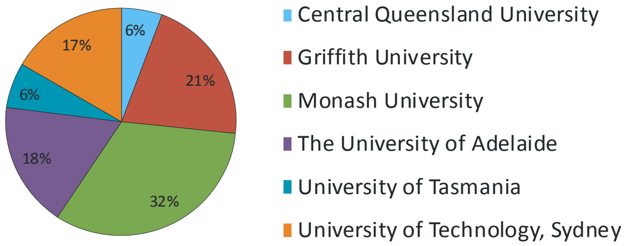


Figure 2. Student survey participation by university (N=157)

We will subsequently present some exemplary and interesting outcomes from the survey, including some noteworthy open-ended responses.

The wide spread of engineering disciplines represented in this survey, especially across the three ‘major’ fields of civil, mechanical and electrical engineering, is apparent from Figure 3. An obvious exception is chemical engineering, since all these students stem from a single, specialised subject at Monash University (cf. closely matching percentages with Figure 2.).

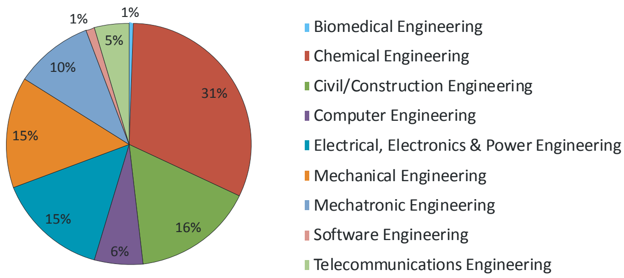


Figure 3. Student survey participation by discipline (N=156)

B. Familiarity and Expectations

We first wanted to investigate the students' previous exposure to remote labs or to remotely controlling equipment. As many as 74% had *never used or heard of it before*, 20% had *heard of it, but never used it before* and finally only 6% had *previously controlled equipment remotely*. Most students who had heard of it referred to power stations, haptics in surgery and some specialized research equipment, but not to remotely accessible laboratories at universities. Some students said they were quite surprised to come across this technology at undergraduate level, while a small number had been using other remote experiments in previous UTS subjects. The relevance of this question will be explained later in the paper.

Flowing on from this question are the first reactions and expectations that the students would have initially had when their lecturer communicated the use of Remote Labs in his/her subject to them. This question generated a lot of attention, with 136 open-ended responses. Frequently occurring comments were:

- *I learn best by myself, so I was excited to have a different form of learning.*
- *I thought it will be hard to use, but also it is kind of cool.*
- *I thought it was interesting but a little confusing as it was very new.*
- *Disappointed that we didn't get to 'handle' the hardware ourselves.*
- *I was surprised to find out it wasn't just a virtual experiment but actually operated equipment in Sydney over the internet.*
- *A bit daunting, and yet another assessment task.*
- *Positive. Saved time on attending residential school which is handy when living remotely.*
- *Excited, since it was my first time using this kind of lab.*

About 90% of the responses indicated a very positive attitude towards the new concept, and we will later contrast this with the expectations that *were* and *were not* fulfilled.

C. Frequency, Time and Place of Usage

Students were asked how often they had accessed a particular experiment during their usage period. The results (per rig type) are presented in Figure 4. The results are interesting, because it can be clearly seen that total access numbers depend on the experiment (or even on the lesson) rather than student numbers alone. For example, in relation to total numbers for each rig, the Shake Table was highly likely to see repeated use by students (mostly 3-6 times), while the Loaded Beam was more likely to be accessed only very few times by students. The responses for the PLC and Coldfire rigs are not representative enough to draw conclusions

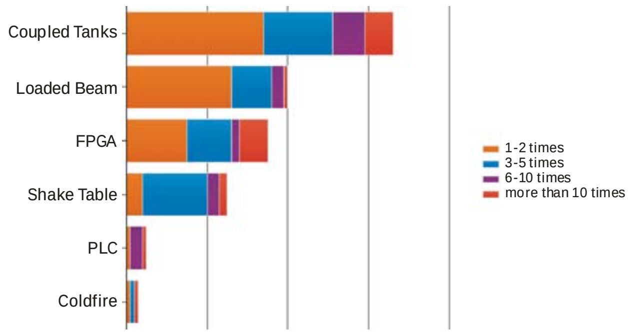


Figure 4. Relative rig usage frequency (in response counts, N=155)

An interesting conclusion can be drawn from the responses to the question *"Where did you access the Remote Labs experiment from?"*, represented in Figure 5. It is immediately obvious that remote labs do not attract much usage while commuting, and very little at a students' potential workplace. Given the likely circumstances in these both cases, the learning objectives of remote labs do not seem to align very well. This realisation mainly has implications for developers of experiments and of accessibility software, since portable devices would represent a very marginal user group for remote labs, according to the survey.

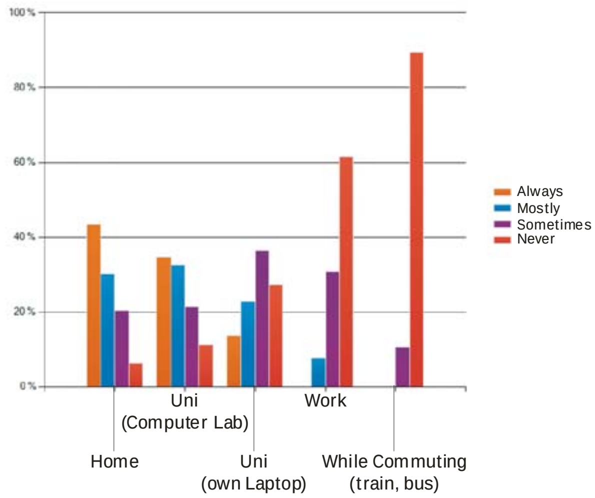


Figure 5. Location and priority of remote labs usage (N=155)

In contrast, access from home and from on-campus computer labs are by far the most likely scenarios. Given the 24/7 convenience of remote labs, usage from home does not seem surprising, however it is almost equally likely that students access remote labs while at uni where they may meet up with fellow students and presumably tackle the assignment collaboratively. Only a minority of students brings their own laptop to university to access remote labs.

The question about the students' preferred access time did not reveal any unexpected outcomes, Figure 6. There is a strong preference for afternoon and evening hours, while morning and late night are usually only chosen out of necessity, such as congestion before an assignment deadline and the availability of computers in a university lab (from comments).

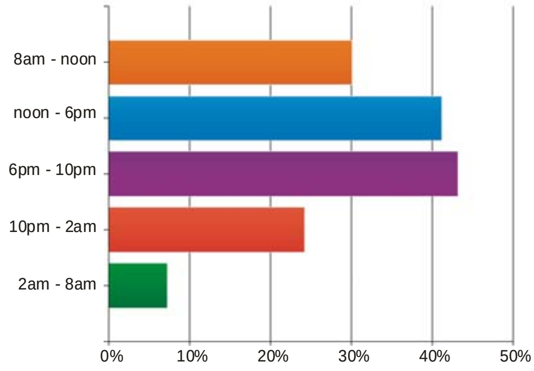


Figure 6. Typical time of the day for remote labs access by students (multiple nominations possible, N=153)

D. Remote Labs Experience

The next survey section addressed the students' personal experience with remote labs, as opposed to learning outcomes. Potentially positive aspects, such as flexibility, and potentially negative ones, such as the absence of a demonstrator, were intentionally mixed, and answers were invited on a 5-point Likert scale. For a number of statements, *Strongly Agree* was the most common rating:

- *I liked that I was able to access the Remote Lab 24/7.* (55%)
- *I liked that I was able to access the Remote Lab from anywhere.* (59%)
- *I liked that I was able to download and save my measurements.* (45%)
- *I liked that I was able to do the experiment in my own time, independently of a fixed timetable and other students.* (56%)

Students *Agreed* by majority with the following statements:

- *The Remote Lab gave me results from a real experiment, not just from simulations.* (49%)
- *The documentation was helpful in guiding me how to operate a Remote Labs.* (54%)
- *In addition to the user interface, it was important for me to have a camera feed for visual confirmation of my actions.* (40%)
- *I trusted the data that I measured.* (45%)

The only two statements where students were mostly unsure (neutral) were:

- *I missed having a tutor to ask questions.* (34%)
- *I prefer Remote Labs over hands-on labs.* (32%)

The last question, which was also the last in this block, was intentionally challenging to critically provoke students' comments. Interestingly, the scale leans slightly (10%) towards remote labs. Some relevant, open-ended commentary (also relating to other statements) was:

- *Hands-on labs are preferable, but not always possible. Remote labs is much better than having nothing.*
- *Despite all the good points of using remote labs for the work we did, I still miss not having the experience of being able to touch the equipment.*
- *The camera did confirm my actions and was very important for me to comprehend what was happening.*
- *Due to not literally being there I find it hard to trust the data.*
- *24hr access from anywhere is great because it provides flexibility.*
- *Remote Labs are good but I would rather use hands on labs. However, remote labs are better than not doing a lab.*
- *Excellent tool for external students in remote areas.*
- *Although remote labs are amazingly convenient, I don't think that they can replace the experience of a hands-on lab.*

The combination of ratings and open-ended feedback firms up the overall student opinion: convenience and accessibility of remote labs are greatly appreciated, especially in those cases where hands-on labs are unavailable or do not offer enough flexibility of access. Video feedback appears to be very effective in installing trust into the measured data.

Another key topic is collaboration. For comparison purposes, most hands-on laboratory classses are conducted in groups, while report writing may still be required on individual basis. The majority of students conducted the remote labs experiment individually, Monash University being the only exception (pairs). We asked students whether they would have preferred – or did prefer – conducting the experiment in a group. Surprisingly, for the overall survey, the result is practically tied: 50.7% would have preferred group work to discuss and share their results with fellow students, and 49.3% indicated that they learn better by themselves. However, there are some very surprising differences between universities in this point, and the interested reader is referred to the companion paper which treats this topic is great detail [8].

E. Learning Outcomes

This section attempts to let the students self-evaluate their learning from the remote labs usage. Questions that address positive aspects of remote labs were alternated with potentially negative statements, and again students were asked to rate them from *Strongly Agree* to *Strongly Disagree*. Key outcomes of this block of questions were:

- Only 14% of students disagreed or strongly disagreed with the statement *"Using a Remote Lab made me feel like I was doing a real lab experiment."* This confirms that most students do not confuse it with a simulated learning environment, but value the 'real world' character of the experiments.
- 63% of respondents agreed or strongly agreed that they were *"…more motivated to 'play' and experiment with the remote equipment, even if not directly relevant for the assignment."* Many cited the extra time they had on the equipment (compared to often time-limited hands-on laboratory lab

sessions) as vital to following an unstructured inquiry-based learning approach in their own time.

- Only about one-third of respondents think that *"…a simulation would achieve the same learning outcomes as a Remote Labs experiment."*, but even fewer believe that simulations could achieve this compared to hands-on labs. Comments indicate students believing that simulations have their valid place in education, but not as a blanket substitute for experiments that could and should be conducted with real equipment, preferably hands-on.
- About 45% of students prefer to *"…manually operate the equipment myself, rather than having a 'ready-to-go' experiment."* Experiments that have to be planned and set up create a longer-lasting and deeper experience for some students, while others are able to learn on a more conceptual level. Interestingly, over 30% were neutral on this question.

- Almost half (49%) of all participating students indicated that they *"…would have preferred access to prompt assistance to help me with the assignment."* With some knowledge of the most frequent questions during the sharing trial, it is likely that 'assistance' in this case refers to technical and administrative help in relation to getting to know remote labs, and only to a lesser extent access to an academic for assignment-related questions.
- The majority of students were either neutral or agreed that they *"…tend to learn better in a traditional lab session than through a Remote Lab."* This response is not unexpected, given the choice. It was frequently mentioned in comments that the best constellation would be a combination of both delivery types with well-selected experiments.

Despite the fairly clear preference for available and accessible hands-on practice, students are generally quite open to using remote labs and recognizing their strengths. When directly comparing certain aspects remote labs with hands-on labs, there are only two points that stand out: 'help and support, if required', followed by 'engagement in the experiment' (Figure 7. Both are certainly very valid and challenging topics, and this result is very much in-line with the opinions of a large number of academics who had also identified engagement as an area where remote labs need to evolve further.

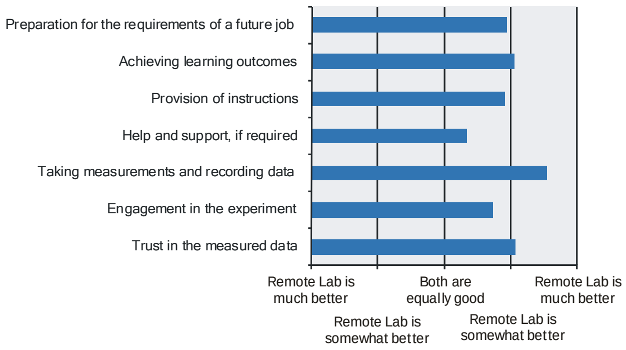


Figure 7. Direct comparison between remote and hands-on labs (average values, N=143)

F. Likes and Dislikes

As a final check to round off the survey responses, we asked students to identify up to three aspects about remote labs that they liked, and up to three that they disliked. The results of this can be seen in Figure 8. 9. Both graphs are on the same scale, and is it easy to see that the total number of 'like' nominations (420) far outweighs the total 'dislike' count (289, in addition to a considerable number of 'I dislike nothing' counts, 19).

In the 'like' category, four features stand out quite distinctly, in order of priority:

1. I didn't have a set time for the experiment.
2. I could repeat the experiment as often as I wanted.
3. The remote lab was easy to use.
4. I didn't have to come to uni to conduct a lab experiment.

This list comprises two convenience factors (1 and 4) and to pedagogic factors (2 and 3). Referring back to Figure 4. students have clearly taken advantage of the opportunity to return to the experiment numerous times, which may be difficult (in most cases) in a hands-on laboratory environment. Ease of use facilitates focusing attention to the desired lesson and learning outcomes instead of dealing with often cumbersome and unrelated issues.

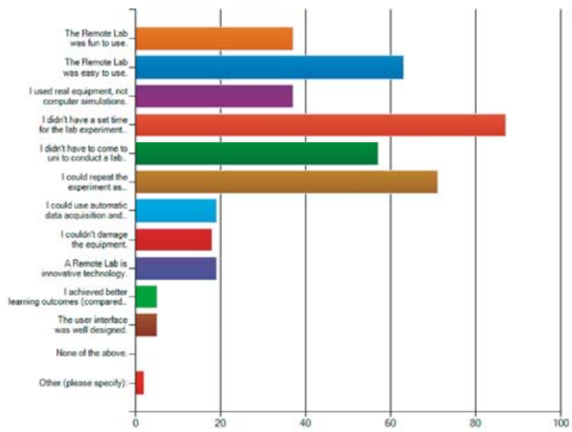


Figure 8. Count of remote labs features that students <u>like</u>, up to 3 selectable. (N=143)

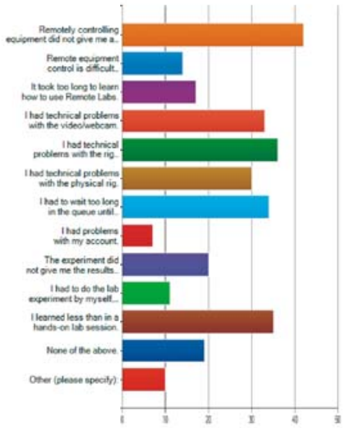


Figure 9. Count of remote labs features that students <u>dislike</u>, up to 3 selectable. (N=143)

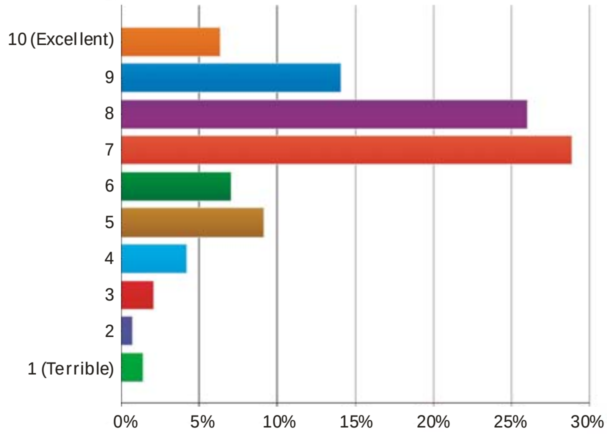


Figure 10. Overall remote labs sharing trial assessment by students (N=142)

On the ‘dislike’ graph, the distribution is far broader and contains fewer outstanding aspects. However, six points can still be identified as having the most weight:

1. Remotely controlling equipment did not give me a good feeling of engagement.
2. I had technical problems with the rig control interface.
3. I learned less than in a hands-on lab session.
4. I had to wait too long in the queue until I could use a rig.
5. I had technical problems with the video/webcam.
6. I had technical problems with the physical rig.

Again, these aspects can be divided into separate groups: technical problems (2, 4, 5 and 6) and pedagogic reasons (1 and 3). Cross-tabbing between technical problems and university affiliation reveals that most of the technical problems are related due to a specific rig malfunction that caused access problems and long queues for one class, so it is not surprising that students include this in their feedback.

As before, the ‘engagement’ issue will certainly need to receive some close attention in the future. Cross-tabbing shows that the subjective judgment of having learnt less is closely tied to the particular class where students had no assignment associated with the access to remote labs and were probably less supported by instructional material and/or tutoring.

G. Overall Assessment and Outlook

Considering all pros and cons, we asked the students to give their experience with remote labs an overall mark out of 10. The distribution of the results is shown in Figure 10. and the average mark across all universities and classes is 7.15, see Table 1.

TABLE 1.
OVERALL STUDENT RATING FOR THE REMOTE LABS SHARING TRIAL BY UNIVERSITY

University	# of responses	Average rating /10
CQ Uni	9	7.6
Griffith	28	6.3
Monash	49	7.1
Adelaide	24	7.3
Tasmania	8	6.0
UTS	24	7.4
TOTAL	142	7.15

Finally, the students were given the opportunity to express their wishes for the future, based on their experience. To the question *“In future, would you like to see more Remote Labs experiments included in your coursework?”* they answered as follows:

- 54 (38%) stated that they would like to see *many* more remote labs experiments.
- 75 (53%) said they would be happy with a few more remote labs experiments.
- 13 (9%) would prefer to leave everything hands-on.

This question concluded the survey.

IV. CONCLUSIONS AND RECOMMENDATIONS

The first, large-scale national sharing trial of remote labs in Australia (and possibly worldwide) has demonstrated that the sharing of facilities between geographically dispersed institutions is achievable, not just on an experimental, but also on an operational level. Within certain constraints of what remote labs can and cannot achieve compared to hands-on labs, students have identified advantages and disadvantages they see for themselves with respect to convenience, flexibility, pedagogy and ease-of-use/technical aspects. This data was obtained from a large, representative sample of students from 10 different classes, and the outcomes of selected quantitative and qualitative questions have been presented.

The reader is encouraged to compare the survey results and student comments to those from [5].

In conjunction with existing access statistics, the results give rise to the following recommendations for future sharing trials to remote labs host institutions and to academics:

- Instruct the instructors: Integrating remote labs in coursework is somewhat different from hands-on lab sessions. Academics without experience should receive special instructions with *dos* and *don'ts* to make remote labs a success. The essentially operational aspects of controlling equipment over the Internet is sometimes an issue, but it's more important for the academic to appreciate the limitations inherent in sharing comparatively small numbers of experimental apparatus amongst large numbers of students. This material is currently in preparation.
- Make it count: Quite naturally, students will only engage if there is a tangible reward for doing so. The student feedback from the one class with an *optional* remote labs assignment was worse than from other participants, because apparently students did not spend sufficient time on the rigs to understand the concept and the functionality to the required extent. It is likely too, that they inferred that the non-essential nature of the exercise indicated the academic placed little value in its successful completion. Compulsory assignments will work best, especially when the students have plenty of time (and motivation!) to experiment and play.
- Make it compulsory: The case study in [9] unmistakably demonstrates that despite considerable investments, students are unlikely to change their habits if given too many options to choose from. The benefits that remote labs provide to both students and the institution will only come about if their role in coursework is clearly defined and openly supported/promoted by the relevant academic and by the faculty/school executive.
- Students will learn: – not just subject material, but also how to accept remote labs as a 'normal' part of their coursework. This feedback survey has already shown that most of the students with prior remote lab exposure gave much higher overall ratings than first-time users.
- Adapt to adopt: The learning outcomes that can be achieved in a hands-on lab and using a remote lab are often different, but that does not mean that one is inferior to the other. The strengths of each need to be identified (and this can be quite individual to the rig, and even to the lesson). The instructional material needs to be changed to reflect this.
- Join the community: It should not only be physical resources like the remote lab rigs that are shared between institutions, but also the lessons that academics have developed to use them. This way, the pool of available lessons for the same hardware will grow quickly, making the sharing of equipment and the learning experience even more efficient and worthwhile.

The Labshare sharing trials are continuing throughout 2011.

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