AAEE 2012 CONFERENCE
Melbourne, Australia
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Barriers to Adopting Remote Access Laboratory Learning Activities

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BACKGROUND

Laboratories form an important part of engineering education and program accreditation. Delivering practical learning activities for distance students is difficult. There have been many initiatives in this space from small scale experiments to large scale national and international projects, such as Labshare (Lowe et al., 2009) and iLab (Harward et al., 2008). Current literature suggests that a lot of attention has been paid to implementation details of individual experiments and systems. However, the impact of learning activities has received little attention. Anecdotal evidence also suggests that these technologies are not widely used as learning and teaching tools. By investigating a number of Remote Access Laboratory (RAL) activities that are hosted in a common environment (Kist & Gibbings, 2010), this study investigates barriers that inhibit the wide application of this technology.

PURPOSE

What are the barriers for inception and implementation of learning activities that employ RAL technology?

DESIGN/METHOD

Five learning activities have been evaluated that make use of RAL technology. The activities are at various stages in the implementation cycle and include learning activities in three different disciplines. A mixed methods approach has been used that included interviews with staff, observations and focus groups with students. A program logic approach (Taylor-Powell, Jones, & Henert, 2003) has been used to map inputs activities, outputs and outcomes of the RAL implementation. Barriers in the conception and realisation process have been identified.

RESULTS

A number of barriers exist that inhibit the wide and rapid deployment of RAL activities. This paper focuses on conceptual and pedagogical issues. Key barriers include: limited understanding of what RAL is and what RAL can do; learning tasks have to be newly defined; and, specific learning activities have to be designed and learning materials have to be developed.

CONCLUSIONS

The paper concludes that from an educational perspective, RAL activities should not be treated differently from any other learning activity and attention should be paid to the principle of constructive alignment. Design and implementation of RAL learning activities is not simply a case of rewriting material for face-to-face delivery, generally, it requires a careful scaffolding of the learning activity.

KEYWORDS

Remote Access Laboratories, practical learning activities, implementation barriers.

Background and Framework

Learning activities that involve experimentation form an important part in engineering education. Remote Access Laboratories (RAL) have been widely advocated as mechanisms to provide access to hardware experiments and systems remotely. On of the key motivation for such systems is the ability to share hardware between physical locations and institutions, for example, remotely controlled robots (Kondraske et al., 1993) or control laboratories (Aktan, Bohus, Crowl, & Shor, 1996); often related economical benefits play an important role (Ma & Nickerson, 2006). Recently a number of projects have taken a more general approach and addressed experiment access and integration, for example, the Australian Labshare project (Lowe, et al., 2009) and the MIT iLab project (Harward, et al., 2008). Research to date suggests that remote access can fulfil many learning requirements and might provide some additional benefits, such as increased and more flexible access for students (Lindsay, 2005; Trevelyan, 2004).

In contrast, objectives for including laboratory or practical work in Engineering or Science curricula are not often explicitly addressed (Feisel & Rosa, 2005). "While course goals are often specified, the literature shows a general dearth of well-written student learning objectives for laboratories" (Feisel & Rosa, 2005, pp. 124-126). "The pedagogical effectiveness of any educational activity is judged by whether or not the intended learning outcomes are achieved" (Arango, Chang, Esche, & Chassapis, 2007, p. 8) but since the instructional objectives for labs are rarely clear, the outcomes of laboratory learning experiences are hard to measure. This also applies to RAL learning activities.

Accepted learning theory can assist in developing a basis for measuring the value of RAL activities and in conceptualising remote laboratory learning activities. Hansen et. al. (2008), concludes, for example, that well-designed RAL activities can offer the following benefits: *flexibility in learning environment, access and approach to the learning task, collaboration with peers and immediate feedback.* The authors suggest that such affordances can promote deeper learning and better connection between theory and practice, greater student engagement through increased control of the experience, and increased inclusivity (Hanson, et al., 2008, p. 165).

White (1996) describes how "laboratory" learning can be conceived of as any instance in which the learner experiences learning "episodes." That is, "events in which the [learner] took part or at least observed," with the result that the experience is "linked to propositions [about facts, concepts, ideas] so that those propositions in turn are remembered and understood" (pp. 765-766). Following this idea, laboratories can be defined as *the physical or conceptual space in which a learning event or experience takes place* and laboratory learning can be defined *as the understanding or knowledge that is created during an event or experience which requires the active participation of the learner and which links 'propositions' to conceptual understandings or application*. Using White's (1996) definition to expand the concept of laboratory into non-science disciplines we suggest that, when a learner takes part in an event or events that connect with their understanding of relevant information, concepts or ideas (propositions), via an online or remote interface, this constitutes a Remote Access Laboratory (Kist, Maxwell, & Gibbings, 2012). This implies that remote access to software can constitute a RAL learning activity.

Analysing publications on RAL it becomes evident that a lot of attention has been paid to the implementation details of individual experiments; however, details on pedagogies in RAL are limited. Besides the fact that details RAL activities have been published almost two decades ago and the advantages these technologies provide, anecdotal evidence suggests that these technologies are not routinely used in teaching environments. This leads to the key motivation for this research project and the research question of what are the barriers to uptake of learning activities that employ RAL technology.

To address this research question, five learning activities in four different disciplines were investigated. All use RAL technology and are hosted in the same environment. Activities are accessible via a common RAL system (Kist & Gibbings, 2010). The system provides mediated and authenticated access to the experiments. This work does not investigate access system related barriers to adoption such as Internet performance or system integration issues. Internet performance and the learning experience in online learning environment are discussed by Kist & Brodie (2012), for example. It is assumed that experiments can be readily accessed by students. The learning activities are at different stages in the implementation cycle, and the evaluation strategies have been adapted accordingly.

The remainder of the paper is organised as follows: Section 2 introduces the methodology that has been used in this study and Section 3 summarises results by RAL activity. Section 4 discusses key barriers and implications of this work. Conclusions are drawn in Section 5.

Methodology

The overall aim of this project was to evaluate the success of individual RAL learning activity implementations. A Program Logic Approach (Taylor-Powell, et al., 2003) was used to map inputs, activities, outputs, outcomes and impacts of each of the five implementations. Figure 1 summaries the logic of the program as it was envisaged by staff.

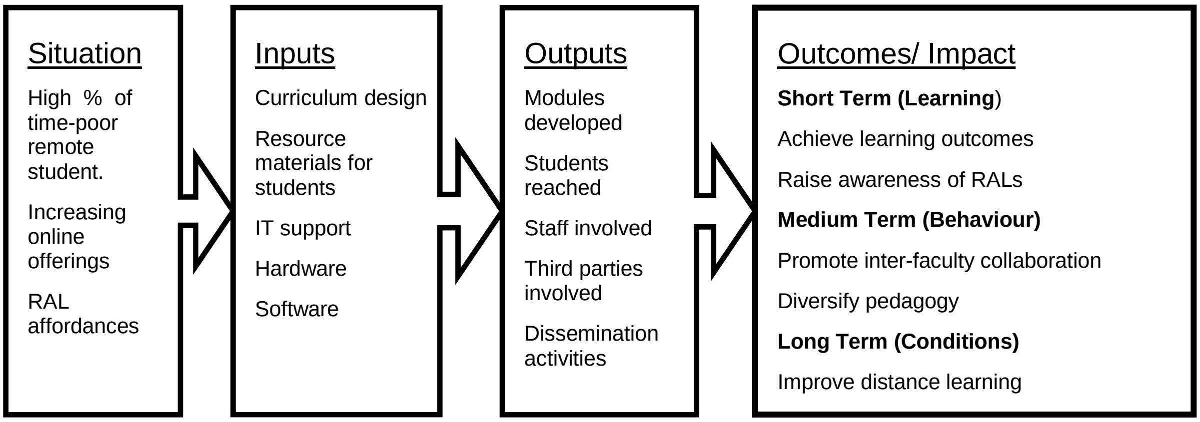

Figure 1: Program logic of RAL implementation

The situation is depicted on the right hand side and includes a high percentage of remote students and the reported RAL affordances. Inputs include the curriculum design, study materials for students, support, as well as software and hardware that are part of the rig. Outputs include learning modules that have been developed, students that have been reached, the stuff and third parties that are involved with RAL projects and dissemination activities. Impact is summarised on the right-hand side and includes achieved learning outcomes for students, diversified pedagogies and improved distance learning.

Evaluation questions were formulated in the areas of appropriateness, efficiency, impact and sustainability of RAL learning activities. To be able to answer the evaluation questions, comprehensive data was collected in relationship to the learning activities. This included interviews with staff members (10 hours), student focus groups (3 hours in three faculties), observations of classes (2 hours), a staff activity diary (Faculty of Engineering and Surveying) and analysis of student work (Faculty of Education). As some of the activities were being developed during the evaluation, on going consultation with the implementation teams was necessary. This ensured that the evaluation remained aligned with the changing focus in some faculties. This also meant that activities were evaluated at different stages in the implementation cycle. The overall project has a much broader scope than the results that are reported in this paper. This paper focuses on barriers to the adoption of RAL learning activities that were identified as part of the evaluation process.

Results by RAL Activity

Software Access (Faculty of Engineering and Surveying – Geographic Information Systems)

In Geographic Information Systems (GIS) laboratories are used as a mechanism for the application of theory. Most practical learning activities are software-based and the RAL infrastructure is used to provide remote access to this software. Theoretical concepts are applied to the creation of maps and graphical representations using ArcGIS software (Esri Australia Pty. Ltd., 2011). Using the extended definition, this constitutes a RAL activity.

The aims as stated in the course specifications are to provide "students with practical knowledge and skills related to geospatial data capture and acquisition attributes database management and GIS [geographic information system] data pre-processing operations". "Hands-on" activities include attribute database management (e.g. creating, editing and expanding attribute tables) and pre-processing operations (e.g. data import and export, digitising and data editing, coordinate and projection transformation, and raster-vector-raster conversions); all software skills. There have been several course offerings that have used the same software. The learning activities were specifically designed for the RAL environment.

For the academic, the most significant task was to rewrite a course that was originally run in a face to face mode. The major task involved the building of scenarios (the virtual laboratory space) and the preparation of materials to support the learning as well as specific materials for the RAL environment. In order to build the virtual lab space "Data were to be acquired (searched), prepared in a desired manner and bring to appropriate size & format. All the data were to be tested prior to posting. Errors were to be rectified as they become visible." This work took 30 hours in total, including liaison with ICT support staff. In addition, writing learning support materials, exercises and questions and organising the online learning system took a further 18 hrs. This was a significant demand on the lecturer but it could be expected that subsequent semesters would see much smaller amounts of time spent in updating and correcting the materials developed.

Students who use the RAL from remote locations were particularly appreciative of the well-structured course which made it possible for them to learn without the necessity of coming to a residential school. This is a clear case in which the use of RAL philosophy and technology has provided more inclusive educational opportunities more efficiently. It was probably helped by the fact that the task was basically an electronic one so that the use of computers for remote access had little impact once the system and the support materials had been created.

Hydraulics Experiment (Faculty of Engineering and Surveying)

This is a classic hardware-based RAL activity of a tapered passage (Bernoulli) experiment. Students can remotely manipulate valve settings and have to determine flow rate and pressure heads. The experiment requires students to apply theory learned in their course to an instance of practice. The experiment is part of course that aims to provide "a broad introduction to the practical aspects of water engineering and focuses on the development of analytical, manual, diagnostic, communication and group interaction skills." Seven students that were taking part in a second year hydraulics practice class on campus took part in a focus group after they undertook the RAL activity online. During the activity, student controlled a device which was set up downstairs in the lab, using equipment that they could control remotely by computer. The student comments below recording during a focus group highlight the difficulties insufficient learning material cause students.

> *M3: Not knowing what to click on, but just to actually start up the program and to log in and all that cos when I did my test, the first time it came up with an error with a…apparently there was an air blockage or, you know, they need to take some air out. You know, how do you know*

> *that if you're doing that from home, because you just get all these numbers and you'd be like 'Oh, it must be right'.*
>
> *M4: You need a good understanding of what you want to find first. Like I came in here, and all the water was stilled up in the…that thing, what is that, the nominator? Yeah, the nominators. And I didn't know they had to be lowered. Like I had a basic understanding, but I just sat there for like…kept doing the experiment and it wasn't working. And then I finally figured it out. But it's like stuff like that, you can waste time. If little things happen down there, then you probably have to call up [name] or someone for the experiment.*

In this case the materials supporting the activity had failed to help some students over the difficulty of knowing what was expected of them. In this kind of RAL it is also common to hear students complain, as they do here, that it is not always easy to tell what is causing hold-ups or mistakes in the experiment.

Robot RAL-ly (Faculty of Education)

Education was the first Faculty outside of Engineering to embrace RAL. In partnership with staff from the Faculty of Engineering & Surveying the academics developed learning scenarios called Robot RAL-ly. In the pilot (Kist et al., 2011) a group of primary school children participated in a three hour workshop designed around the National Curriculum Mathematics learning objectives of map-making and scale. The task involved children designing, mapping and then building to scale racing tracks for remote controlled robots. After this was completed, the children raced the robots through their race tracks from an isolated room in the university, using RAL technology. This trial demonstrated the technical feasibility of the RAL system, using multiple data and video feeds to enable children to manipulate the robots remotely in real time.

This same approach was then deployed from a distance in Robot RAL-ly Japan (October, 2011). In this pilot project, the children in a classroom in Osaka, Japan did the design and mapping, whilst another group of children at the Toowoomba Campus of USQ built the tracks to scale following their Japanese colleagues' design. The children in Japan then raced the robots through the tracks via the RAL system, using the high-speed broadband access available in their school. In both pilot projects, both boys and girls were highly engaged in the learning activities. This included, for their level, very complicated mathematical calculations.

Student reflections from the Japanese trail of the Robot RAL-ly were overwhelmingly positive. When asked "Give the whole project (all 3 days) a score out of 10 for how much fun it was", the class average result was 9.15 out of 10. However, students' reflections on what they learned out of experience mentioned the motivating effect of using maths in a 'real' situation and being involved in activities such as testing, drawing, designing and working with the various parts of the robots. As one student commented, they learned that 'we can learn from almost any situation'.

Conceptual Tool (Faculty of Education)

Academics in the Faculty of Education have also explored the application of RAL as a conceptual tool to allow student teachers to practice the integration of inquiry-based pedagogy; curricular objectives from a range of key learning areas; and, activities which involve using technology in an instance of lesson planning. Student teachers had previously viewed the Robot RAL-ly trials as an exemplar for this task. Within their lesson plan, they were to describe and justify the educational outcomes of a similar use of a RAL tool by school-age students. They were also required to consider how the affordances of this teaching approach could persuade the principal of a school to buy into a RAL system or program.

Through reviewing a selection of submissions from student teachers, a number of conclusions are apparent. Although the students were able to explicitly state the curricular outcomes of their lessons, the RAL activities that student teachers designed for their school-age students were not significantly different from the Robot RAL-ly exemplar that they were provided with. Although they seemed to see the affordances of this learning experience exemplar, their submissions demonstrated a recreation of these affordances, rather than a development of new ones. There were no instances in which the student teachers sought to justify what it was the RAL could deliver which could not be provided in any other way, for example through the use of a low-tech, proximal experiment. Students who attended a focus group indicated that there were a number of problems for them in understanding what they were required to do with it. They could not describe how they might use RALs in their teaching beyond using it to allow students in “Alice Springs or somewhere like that” to do science experiments remotely. They reported working on the project in teams in which work was divided by topic amongst the team members. This meant of course that only one member of the team paid any attention to the RAL and it seems likely that this contributed to the reported vagueness about how teachers might use RALs.

Practice Clinical Reasoning (Faculty of Science – Nursing)

Academics form the Department of Nursing and Midwifery together with academics from the Faculty of Engineering and Surveying have developed a remotely accessible infusion pump. The RAL learning activity is used as a vehicle for rehearsing professional practice skills, i.e. anaesthetic delivery to patients and will be used as a student nurse training aid. Besides the mechanical aspects of calculating flow rates, students are expected to develop “clinical reasoning” skills.

A face-to face class was observed in August 2011. After an introductory talk about the procedure by the lecturer which included demonstration of taking the cap off the fluid bag, piercing the bag, priming the line and clamping the line before inserting the line into the infusion pump. Students were split into groups and given “case notes” for their simulated (plastic) patient and had to prepare the pump, calculate flow rates and familiarise themselves with the pump interface. They had to begin to understand the various alarms the pump emit and what to so in response to each. There are clearly aspects of this exercise that could not be replicated remotely, but the lecturer was envisaging the RAL as extra drill for students which would build on this first experience.

The case study format with a fake patient in the bed meant that students could practice discussion of medical information, processes for handing patients over to other practitioners, and complete immersion in the bedside experience as well as the handling of the pump. Students generally struggled with getting the pump to work and found the beeping alarms disconcerting. Working in teams of four meant some delays in everyone getting a chance to practice manual skills, but provided a resource for working out responses. There is clearly a wealth of pedagogical content knowledge embedded in the design of such a class and the risk in developing a companion RAL is that the mechanics of the procedure will dominate at the expense of the other clinical skills.

A focus group was held in October 2011 with nursing students how they might use such a RAL activity. Twenty-six students attended the focus group and there was a great deal of enthusiasm for the idea of an electronic aid to learning the pump procedures which they described with words like “frustrating”, “daunting”, “overwhelming”, but also “quite interesting, actually, the pump checks in on you, what you’re doing, that you have to put the line in a certain way”. A RAL to practice on would, in their estimation, get over the problem that in a face-to-face class, if the first person in the group struggles the rest don’t get much time to familiarise themselves with the procedure.

They also cited the fact that the time between classes when they get to practice the skills is long and they tend to forget things. The most obvious advantage was the flexibility of access, allowing them to practice at their own pace in their own time with as many returns to the procedure as necessary to keep it fresh in their minds. In short, these students were looking for some of the things often claimed as the benefits of RALS; flexibility of access and the opportunity for repeated practice (the Remote part of RAL) but were sceptical of the RAL's ability to deliver those other vaunted benefits: collaboration with peers and immediate feedback. These are characteristics of RALs which depend heavily of the pedagogical design of the RAL and of the course using it.

Barriers Highlighted by the Results

Barrier can be indentified in a number of areas and from a number of vantage points, e.g. individual and institutional, or student and academics points of view. Butler & Sellbom (2002) highlight a number of barriers in the context of technology adoption for learning and teaching. Key factors include reliability, knowledge of how to use technology, evaluation and institutional support. Taking a broader view, these observations apply in the context of RAL as well. However, pedagogical aspects are also a key concern. The discussion in this section focuses on barriers from academic, educational and pedagogical perspectives.

The evaluation has identified the following barriers to the inception, design and implementation of RAL learning activities:

1. Understanding of RAL and what it can do in an educational context,
2. Understanding of pedagogy in these environments,
3. Rethinking of learning tasks,
4. Learning activity development and pedagogical design,
5. Technical expertise to implement RAL activities,
6. Time and effort required.

The first barrier to conception of learning activities is the difficulties academics face in understanding RAL in an educational context. On one hand, the activities in the Faculty of Education provide examples for the innovative and lateral use of the technology for the Robot RAL-ly and the conceptual RAL activity; on the other hand, the limited proposals by the student teachers highlights difficulties people can face in understanding the possibilities of RAL technology in an educational context.

Such difficulties were also encountered in the initial phases of both the Robot RAL-ly project and the initial stages of the project in the Faculty of Science. One way to address this issue is to expose interested parties to other examples of RAL activities. The experience in this project also showed that collaboration of interested parties from multiples disciplines lead to the best outcomes.

The second barrier relates to the first barrier and concerns an understanding of pedagogies that are relevant for RAL learning activities. How can RAL be used and what pedagogies are appropriate in these contexts? Educational literature provides some guidance on how online learning tools can be used; however, research into specific pedagogies of RAL have been very limited. This makes it one of key areas that need to be addressed by educational research on RAL in the future.

The third barrier is perhaps more consequential overall. Using a RAL, in most cases, is not just going to be a matter of re-writing something that already exists for remote access. It will require rethinking of the learning task within the kind of definition of laboratory that has been discussed in this paper, and then a course design that makes best use of that experience to reach the desired learning outcomes.

The evaluation suggests that more attention needs to be paid to the principles of constructive alignment which directly relates to the forth barrier. An example of this issue is evident comparing the software and the hydraulics activity. To address this may require staff training whether in formal settings such as Postgraduate Certificates in Higher Education courses, or through local initiatives of the Learning and Teaching Support Unit.

Barriers relating to the expertise that is required to develop and operate activities include the technical knowledge, Information and Communication Technology (ICT) support, technical support and ongoing operational support. The last factor is not RAL specific, however was common to all projects. For the projects discussed here, this barrier was mitigated by the involvement of academics from the Faculty of Engineering and Surveying that had the required expertise. For courses that lie outside the engineering and surveying faculty, where the technical expertise resides, just getting the appropriate technical support can become a major hurdle and lead to delays in implementation or compromises on what is possible.

The final barrier is the time and effort needed to do the course redesign to include RALs in existing courses or build new courses around them. As we saw from the spatial science example, even in a course which was always heavily electronic in nature, rewriting took 48 hours. Many courses would expect to take longer than this. This was also evident for the other projects. Academic time to develop activities and materials was a real limitation to what could be achieved.

Conclusions

The extended definition of RAL as a conceptual space allowed for the investigation of five RAL activities in four different disciplines. This broad view led to a comprehensive evaluation and provided a better insight into barriers to the adoption of RAL activities from a pedagogical perspective. Some of the issues, such as difficulties in understanding the concept of RAL have not been directly encountered by academics in the Faculty of Engineering and Surveying; these might however apply to other academics that did not get involved with the project. Developing RAL activities is not a case of simply reproducing face-to-face classes in a remote environment, carful attention is necessary to scaffold the learning activity and applying the principles of constructive alignment. One of the main barriers for time-poor academics is the time it takes to make such changes to the course delivery. The key to overcoming most other barriers was the collaboration between academics in different disciplines. This allowed for reflection and rethinking of learning tasks, but was also very important for designing and developing new learning activities. A community of practice could provide a formal environment to support individuals that are interested in developing RAL learning activities. In contrast to the barriers, the potential gains for students, both in terms of engagement and learning, make RAL learning activities a very worthwhile endeavour.

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Acknowledgements

The authors would like to thank the various academics, laboratory managers and students who participated in this study. This work has been funded by a USQ LTPF grant. The authors would like to thank Lesley Jolly and Hannah Jolly, Strategic Partnerships, for their assistance with the evaluation.

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