# AC 2012-5244: EXPANDING THE CONCEPT OF REMOTE ACCESS LABORATORIES

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# Expanding the Concept of Remote Access Laboratories

**Abstract:** The ability of students to participate in laboratory experiences remotely through appropriate technologies has obvious utility for students who are distant from university campuses for whatever reason. This need is experienced in many faculties and this study reports on a project exploring how Remote Access Laboratory (RAL) technologies developed to enhance engineering education can be used to support learning in non technical faculties such as business, arts and education. To take this step, it is necessary to expand the traditional definitions of RAL leading to a range of interpretations of the concept of remote access laboratories; from the traditional, physical and tangible experiment, as is frequently seen in the engineering applications of RAL, to more conceptual experimentation in any form which is conducted remotely. The study focuses on five projects in the Department of Nursing and Midwifery, the Discipline of Surveying and Spatial Science, and the Faculty of Education. Using a program logic framework approach, the project aims to elucidate the pedagogic logic in a range of learning situations and evaluate the usefulness of RAL in each of them. This paper argues that by expanding the concept of remote access laboratories, applications in non technical disciplines are possible and finds that the use of RAL is limited only by the imagination of the teacher and the nature of the learning objectives. It also suggests that the concepts that are currently being applied in engineering RAL applications should be re-evaluated focussing on constructive alignment. On the basis of learning affordances they provide, that these technologies deserve to be, and can be, developed for wider application across all disciplines in order to address the needs of target demographics but also because they offer exciting new ways of providing quality learning to all students.

## Introduction

Experiments and learning activities in laboratories play an important part in engineering education. The ability of students to partake in laboratory experiences remotely through appropriate technologies has obvious utility for students who are remote from university campuses. Early key motivators to provide remote access included the ability to share hardware between physical locations and institutions, for example, remotely controlled robots[1] or control laboratories;[2] and related economical benefits.[3] Many of these early activities focused on individual solutions to specific experiments that are not transferable to other disciplines. More recently a number of projects have taken a more general approach and addressed experiment access and integration; however, the focus on engineering and science experiments remains.

The Australian Labshare project[4], for example, aims "to create a (nationally) shared network of remote laboratories that results in some combination of: higher quality laboratories; greater student flexibility; improved educational outcomes; improved financial sustainability; (...)". Another infrastructure approach is the MIT iLab project[5] that has developed a software toolkit to promote the sharing of laboratories via the Internet. These initiatives largely focus on alternatives to hands-on, proximal laboratories to provide access to expensive hardware. Research to date suggests that remote access can fulfil many learning requirements as the traditional proximal laboratory experience, as well as providing some additional benefits, such as increased and more flexible access for students.[6, 7]

Whilst the value of the simulated mode is generally acknowledged, the Remote Access Laboratory (RAL) literature usually ascribes importance to the existence of physical equipment, which the students manipulate and receive real feedback from.[8] Remote laboratories are often (sometimes implicitly) defined by the presence or absence of physical equipment.

In the context of distance education, the use of Information and Communication Technology (ICT) to provide learning activities in online environments has become an important topic. Our project has extended this definition of RAL by including software experiments with the understanding that remote access laboratories are also tools for offering more equitable opportunities for distance learning across the higher education sector. The RAL system at the University of Southern Queensland has been developed to provide access to computers located on-campus. This allows external students (studying off campus by distance education) to use software and hardware remotely. The RAL facilities originally developed by the Faculty of Engineering and Surveying at the University of Southern Queensland (USQ), is now a university core system and available to all users.[9] As USQ relies heavily on distance and online study, the system is particularly important to give students an equivalent experience to their campus peers. There is a strong focus in the literature[4-7] on remotely accessed learning activities in the engineering and science disciplines; however, there is limited work on how such learning laboratories may afford valuable learning outcomes in other faculties or disciplines. Partly, this may be due to factors surrounding how remote laboratories were originally developed and defined.

To explore this, a research project is currently being undertaken to investigate the pedagogy of RAL in faculties other than engineering. The overall research question of the project focuses on benefits to teaching and learning the RAL tools can offer in other faculties and how. Specifically it focuses on which issues exist for the implementation of these tools in other faculties. This paper argues that to take this step it is necessary to expand the traditional definitions of RAL leading to a range of interpretations of the concept of remote access labs; from the traditional, physical and tangible experiment, as is frequently seen in the Engineering applications of RAL, to more conceptual experimentation in any form which is conducted remotely. This has direct implications for engineering education as it highlights how changes in the approach to remote access laboratories can impact on the student learning experience and how well learning outcomes are attained. By expanding the scope of RAL, it can be demonstrated that RAL-based learning tools can become vehicles to overcome access issues in providing learning tools such as software and hardware in the context of distance education, but also as a tool to provide access to technology for disadvantaged groups and promote inclusivity.

The remainder of the paper is organised as follows: Section 2 discusses related literature and establishes the theoretical framework for this project, Section 3 introduces the study and Section 4 reports initial findings and work that is currently underway. Section 5 highlights implications for RAL in the context of engineering education.

## Theoretical Framework

Learning theory which points to the advantages of incorporating laboratory learning in courses can form the basis for measuring the value of RALs. White[10] describes how laboratory learning has the potential to create "episodes:" "recollections of 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). Therefore, the laboratories and learning experiences should be understood separately. The former comprises a physical or conceptual space in which an event or experience takes place, the latter, the experience itself allows the application of knowledge to develop skills and understanding.

Taking this broader view of what can constitute a laboratory learning experience allows for greater flexibility in understanding the concept and application of remote access laboratories. If a learning experience can be created in which the 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 can be seen to constitute a remote access laboratory.

Barak[11] derives four principles from behavioural, cognitive and social learning theory which underpin the effective design and use of ICT-based lab work, i.e.

- "learning is contextual
- learning is an active process
- learning is a social process
- reflective practice plays a central role in learning" (pp. 122-123).

These principals are not discipline specific and have to apply to any RAL learning activity. They are used for the evaluation of the RAL activities in other disciplines in the body of the study.

Slangen and Sloep[12] suggest that it is important to provide an "environment in which the pupil can construct knowledge and can reflect upon his interactions and thinking" and highlights that "learning implies the initiation of a thinking process" (p. 228). The integrated thinking model of Jonassen[13] cited by Slangen & Sloep[12] highlights three general thinking tasks, i.e. basic, critical and creative thinking that are part of a complex thinking process. Slangen & Sloep[12] suggest that the effective use of mind tools promotes fluency in different ways of thinking described in the model.

For a laboratory learning experience to the complex thinking processes, it must qualify as a "mind tool." Jonassen, Carr & Yueh[14] propose that "mind tools are computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying …" and "they require students to think about what they know in different, meaningful ways".[14p.24] If RAL can be classified as a mind tool will depend on the particular activity and the underlying learning outcomes. Ultimately, RAL has to deliver the intended learning outcomes independent of the discipline in which it is used as "the pedagogical effectiveness of any educational activity is judged by whether or not the intended learning outcomes are achieved".[15]

Figure 1 depicts two concept maps that summaries these notions in the context of RAL. The right map provides a broader view; the left map shows a learning episode in detail. RAL is made up of experiments which provide the space (conceptual or physical) for learning episodes to take place. RAL is therefore the enabler for these learning episodes. Learning outcomes define the nature of the learning episodes. Context and social environment impact on how these episodes are experienced by the learner. Details of learning episodes are shown on the right. Activities allow the application of knowledge and ideas to develop and practice skills; and help to understand theoretical concepts. The following discussions show how the initial RAL activities in this study align with Barak's principles and how RAL serves as a “mind tool".

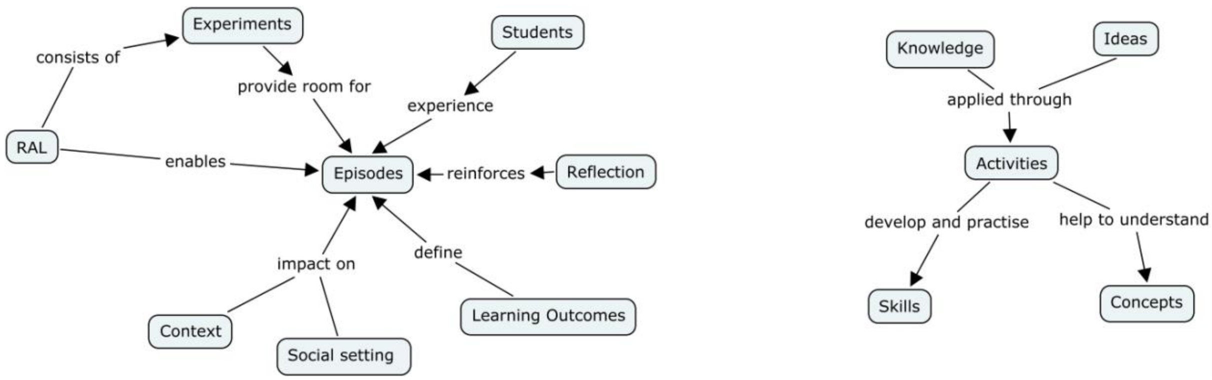


Figure 1: RAL Concepts

**Current Study (Methodology)**

Based on this framework, the project has engaged with all five faculties at USQ via the Associate Deans Learning and Teaching. Whereas all were very supportive of this initiative, currently there are no active projects in the Faculties of Business and Law; and Arts. The study focuses on five projects in the Department of Nursing and Midwifery (Faculty of Science), the Discipline of Surveying and Spatial Science (Faculty of Engineering and Surveying), and the Faculty of Education. The projects are summarised below and discussion revolves around how they relate to Barak’s criteria introduced in the previous section.

Discipline of Surveying and Spatial Science

In the Discipline of Surveying and Spatial Science, laboratories are used as vehicles for the application of theory. Activities in the practical course that is the focus of this study are largely based on software and RAL provides remote access to this software. Theoretical concepts learned in the course are applied to the creation of maps and graphical representations using ArcGIS software[16]. The learning objectives 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”. Practical skills in the context of this laboratory relate to software skills such as the interpretation of images.

“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 GIS activity addresses all the principles listed above: teaching is contextual as it is practice based and applied and it is active as student use software to accomplish tasks. Social interaction in this context is occurring online on the learning management system via discussion groups as well as other interactions with peers and the lecturer. As these are distance education students they are used to online interactions. Students reflect on their activities when they prepare and submit results obtained using RAL as an assignment.

Faculty of Education

The Faculty of Education has embraced the concept of RAL in a number of ways. Three projects are outlined below that employ RAL at student, curricular and faculty levels. Robot RAL-ly is an activity that uses RAL laboratories as a vehicle for the integration of a variety of curricular objectives in education using one tool (e.g. mathematics, science and ICT objectives). The remote access technology was employed in a workshop for primary school children called Robot RAL-ly.[17] The participants designed a racing course for remote-control robots, and then moved to a different room to manoeuvre the robots through other teams' courses using the RAL technology. At the end of the workshop, the children participated in a co-constructed focus group discussion.

Initial project outcomes include the observations that engaging primary school children with Engineering topics not only provides valuable insights for engineering education but also helps to make engineering more accessible to potential future students. The use of RAL in this context followed the traditional lab model. Students experience the physical as well as the virtual, remote lab space. The learning is still contextual and active. The social component is more evident in this context as the students worked in teams and the project facilitators encouraged reflective practices during the activities.

Academics in the Faculties of Engineering and Surveying; and Education have also identified the benefits that the collaboration surrounding the Robot RAL-ly have provided and this in itself has become the focus of an investigation. The multidisciplinary nature of the Robot RAL-ly project and the positive outcomes for both disciplines lead to the understanding that RAL can also be used as a vehicle for pedagogical conversations among staff about how to diversify pedagogical tools. The project demonstrated that cross disciplinary projects benefit all parties. Again the learning (of the academics) was contextual and active as well as social. Reflective practice played an important role during the conception, implementation and debriefing stages of the Robot RAL-ly project.

The concept of RAL is also used as a vehicle for methods of inquiry in a course called Inquiry through the Curriculum with the aim for students to develop skills, knowledge and understanding in the key learning areas of Science, Technology, Engineering, and Mathematics (STEM). The course includes an assignment where RAL is being used to encourage the adoption of particular (inquiry-based) pedagogies by student teachers in their lesson planning. A group of students had to develop a proposal to a local school principal to promote the use of RAL for inquiry based learning in relation to STEM. In the current form this is only a conceptual lab. Although this is only a conceptual RAL activity, it addresses all four principles for the effective use of lab based work.

Department of Nursing and Midwifery

The Department of Nursing and Midwifery is currently undertaking a project where remote laboratories are used as a vehicle for rehearsing professional practice skills, i.e. anaesthetic delivery to patients. The project's aim is to develop a prototype of a remotely accessible infusion pump. The activity will be used as a student nurse training aid. Further goals of the study include the development of software that will support online student learning using principles of digital pedagogy and measure clinical reasoning. This project is in the development phase and it is anticipated that the prototype will tested in Semester 1 2012. On first impression this activity is similar to typical RAL activities in engineering; however, there is a major difference in anticipated learning outcomes. In engineering, learning outcomes usually relate to understanding the operation of technical equipment and related phenomena; here the key learning outcomes relate to the use of the equipment and related clinical reasoning skills.

**Next Steps and Initial Findings**

At the beginning, the study focussed on a laboratory activity that could be applied generically in a number of disciplines, in order to explore the outcomes and affordances these could provide. The aim was to find a lab experience that is comparable and adaptable. Even though many courses include similar skills in their learning objectives, such as communication, teamwork, problem solving or reflection; it was difficult to find a common practical activity suitable to RAL. Another issue with this approach was the timeline and the various levels of engagement of potential stakeholders in other disciplines. For the current approach, this is not a factor. Furthermore, the expanded definition of remote laboratories asked for a more open-ended approach to better allow participating disciplines to explore uses of this technology. The discussion of the activities above demonstrates that there are other applications for the concept of RAL than the control of physical equipment. In particular, the projects in the Faculty of Education show that RAL can be used in many ways.

To formally evaluate the individual projects, a systematic evidence-based methodology was chosen. A Program Logic approach provides the means to map a program or intervention and evaluate how it achieves its objectives.[18] Here it was used to describe and map the entire program, from the goals and objectives of using RAL in each faculty and to the inputs, activities, outputs, outcomes and impacts of each of the programs which use RAL. In so doing, it became possible to map the intended and actual benefits and outcomes of using RAL for different purposes and different contexts.

Data from the program environment and the participants in the program have been captured in the form of observations of behaviours and activities as well as the participants' perspectives on the programs and their own learning. This methodology has the potential to reveal not just the amount of benefit but the nature of the benefit that is afforded by RAL tools, and the conditions that are necessary for this benefit to occur. The project will add to our understanding of how RALs work, how they can be made to be useful and what their overall potential for teaching and learning is.

The project is ongoing and a number of implementations are underway; however, only limited tests with students have taken place so far. Whereas detailed results are outside the scope of this paper, information from implementation in engineering and discussion with nursing students allow for initial broad conclusions about the impact of RAL in the context of this project.

While students see the use of RALs for practicing their skills at their own time and pace, they are impatient if there are any technical difficulties and glitches in the system, especially if it makes free interaction with RAL and pursuit of their intended learning difficult. Where such glitches have been ironed out well in advance and adequate training and support materials are provided, as in the spatial science course, students appreciate the advantages of the RAL.

Two major barriers to implementation of RAL activities have been identified. The first is the time and effort needed to do the necessary course redesign to include RALs in existing courses or build new courses around them. For courses outside the engineering domain, getting the appropriate technical support is a major hurdle and led to delays in implementation. The second barrier is perhaps more consequential. Using a RAL, in most cases, is not just going to be a matter of re-writing existing material for remote access; it will require rethinking of the learning task within the kind of definition of laboratory that we have provided above, and then a course design that makes best use of that experience to reach the desired learning outcomes.

This suggests that more attention needs to be paid to the principles of constructive alignment.[19] This may also require staff training whether informal settings such as Postgraduate Certificates in Higher Education courses, or through local initiatives of the Learning and Teaching Support Unit. Technical and training support will be central to further uptake of RALs across the university and to support the ongoing effort in the Faculty of Engineering and Surveying.

**Implications for Engineering Education**

Laboratory activities are critical components of engineering education and are important for program accreditation by professional bodies such as ABET or Engineers Australia. Exposing other disciplines to concepts of engineering laboratories is in itself a valuable activity making engineering more transparent; however, this research project has also direct implications for engineering education and the way remote access laboratories are integrated in the curriculum.

As remote laboratories are generally designed by engineers, the focus is often on technical implementation details, instrumentation and how rigs are automated to make it remotely accessible. Most publications in this area fit into this space. From a student and learning perspective, a scaffolded integrated learning experience is more important than intricate implementation details. This is not to say that technical details are not important, but if a RAL rig is used as an online learning tool, attention to pedagogy of the activity is important and necessary.

Expanding the definition of remote access laboratories allows applying similar pedagogies across a wide area of activities. Initial results of this study indicate that design and delivery is key and applies to all activities. Evaluation showed that the best integrated and scaffolded activity from a learning and teaching perspective was software based. The activity is well received by students resulting in the intended learning outcomes. Interestingly, such an activity would not be included in the traditional definition of remote access laboratories that requires physical gear to be manipulated. On the other hand, there are activities in a hydraulics lab, that are well integrated from a technical point of view, but students struggle as the learning activities are not well integrated from an educational perspective.

The effectiveness of laboratories, in general, and the relative effectiveness of traditional laboratory experiments compared with RAL experiments is an important open research question. In the context of this research project, however, this has not been a direct focus. Many disciplines do not use laboratory activities as such. The aim is to demonstrate that (RAL) addresses learning outcomes. The level at which they are attained will demonstrate the effectiveness for the RAL activity.

Accreditation is important for engineering programs and until now virtual laboratories have not been acceptable for accreditation bodies such as ABET or Engineers Australia. However, recent work indicates[20] that there are no compelling reasons why some laboratory activities could not be completed remotely. The key measure is if learning outcome are meet and necessary graduate attributes are acquired. This relates directly to the discussion above: A remotely accessible rig in itself is not acceptable; however, an integrated learning activity that demonstrates that certain skills are acquired might be adequate.

## Conclusions

The different approaches highlighted in this study have shown that the concept of RAL as an episode expands the relevance of this learning tool. RAL can be an important tool to promote inclusiveness and address access issues. In traditional laboratories it is about access to software or hardware which is necessary for the practical application of theory; in nursing it is about access to hands-on contact with equipment; in education it is less obvious - RAL provides means of enacting pedagogical theory. This study also has implications for Engineering Education. Insights gained about the use of RAL, as a pedagogical tool can be readily applied in the Engineering context. RAL has a great potential and can be used in many more ways and for many more benefits than it is at present. As these benefits are largely offered remotely, RAL is particularly relevant in the context of distance education but can also play a role in improving opportunities for remote communities.

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