

Exploring a cross-disciplinary research initiative with Remote Access Laboratories: Robot RAL-ly as a stimulus for consideration of Engineering pathway

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***Abstract:** A well-established project exists within the Faculty of Engineering and Surveying at the University of Southern Queensland (USQ), where students are provided remote access to video-supported laboratory experimentation so as to actively engage in contextual action-orientated learning. In this paper we describe a project in which Remote Access Laboratory (RAL) technology developed for university engineering academics at USQ was expanded to explore the cross-disciplinary application of the system. A team of academics from USQ's Faculty of Education joined the existing RAL technology team from the Faculty of Engineering and Surveying to develop a workshop for primary school children. The children were aged between seven and twelve, and included both boys and girls. This project aimed at providing a stimulus for these children to engage in Engineering-inspired activities so as to promote this as a possible pathway for further study. At the end of the workshop, the children participated in a co-constructed focus group discussion. A thematic analysis of this focus group recording indicates that the remote manipulation of real objects provides children in this age-group with opportunities for rich learning experiences. The initial perspectives of academics were also explored through critical reflection on the program's design and delivery and a thematic analysis was performed. The paper concludes that, regardless of access and mode of study or discipline background, high quality interactions, with peers and academic staff in an informal context, are vital to the building of enhanced capacity for rich learning experiences and motivation for further experimentation.*

Introduction

The development and use of technology to enable Remote Access Laboratories (RAL) at universities is not a new practice and in fact, is well established in the engineering disciplines (Corter & Ellis, 2002; Kist & Gibbings, 2010; Ma, 2006; Tuttas & Wagner, 2001). Practical and laboratory experiments form an integral part of engineering education programs and are seen as a requirement for program accreditation (Kist & Gibbings, 2010). Within the field of engineering, research tends to focus on technical feasibility and development efforts of remote access laboratories. There is very little focus on the pedagogical implications of the integration of such technology into curricula. Key pedagogical aspects pertinent to the integration of RAL in engineering education remain contestable. While there is some evidence to suggest that the learning outcomes are not significantly different whether laboratories are accessed proximally or remotely (Trevelyan, 2004), other evidence suggests that learning outcomes differ significantly according to mode of access (Lindsay, 2005). Furthermore, to date there is very little scholarly literature around the application of RAL to disciplines beyond engineering and, in particular, how such technology can be used to connect with distant schools and other educational institutions so as to engage with the broader community and promote engineering as a potential tertiary pathway.

The integrated use of ICT technologies within learning and teaching environments is both a general public expectation, and an official requirement for schools in Australia (Fetherston, 2007). As such there is a direct need to evaluate and further investigate methods and procedures in which ICT can be used as either a significant enhancement, or a driver for the learning and teaching experience rather than just an embellishment (Goodison, 2003). In this paper we describe the collaboration between two faculties, implementing RAL technology to enhance student learning for primary school children. Concomitantly, this creates an opportunity to promote engineering as a potential tertiary pathway for these young students.

The RAL system was developed by a team of engineering academics at the University of Southern Queensland to provide access to practical learning experiences for off campus students, with to the aim of providing an equivalent experience to that of on-campus peers. The feasibility and effectiveness of remote access labs for engineering and tertiary education has been well documented. However, to date little work has been performed in how such learning laboratories may facilitate valuable learning outcomes in other faculties or disciplines and to also the application for broader community engagement.

In collaboration, a team of academics from USQ's Faculty of Education and the Engineering and Surveying staff, worked together to design and implement this RAL technology in a three-hour workshop for primary school children designed to promote their interest in engineering. The primary objective of the 'Robot RAL-ly' workshop was initially to explore the pedagogical extensions and possibilities of the RAL technology in non-technical applications. In this instance, a learning activity was developed for thirteen primary school children aged between seven and twelve years, comprising both boys and girls. The design of this activity was based on current curriculum priorities and pedagogical practices endorsed by the Queensland Studies Authority (QSA), the statutory body overseeing education in Queensland, Australia.

Remote Access Laboratory

Practical elements are by necessity an integral part of the education of engineering students. The Faculty of Engineering and Surveying (FoES) at the University of Southern Queensland has a unique student cohort when compared to other Australian universities. At present, approximately 76% of students studying at USQ do so in an external, or distance mode, in which most of their on-task study occurs away from the USQ campus. This presents particular challenges in order to facilitate the practical element of their education. Present solutions involve compulsory attendance at residential schools at which these student cohorts complete these activities on campus. This presents particular problems due to the disjointed timing of course work and practical elements. It has been argued that this affects learning outcomes and engagement within courses.

To address these issues, FoES has undertaken a project to develop an arbitrated process of access to both software and hardware experiments relevant to course structure in the form of the RAL. This provides benefits to students in several ways by providing immediate delivery of software and hardware experiments to students over the internet, providing flexibility in that delivery, a cost and time effective service to students and a direct link between both practical and theoretical knowledge. Whilst the RAL system has been designed as an integrated service into the university's Learning Management System (LMS) it remains flexible enough to allow research activities based on RAL technology, as well as to integrate with community RAL events.

As the RAL system becomes more available to the university as a core system, a project is in progress to extend this capability to non-technical disciplines as a means to establish and gauge effectiveness in teaching and flexibility of delivery. This non-technical RAL event, called Robot RAL-ly, utilised a custom RAL experiment packaged into a portable rack-mounted configuration comprising of Web enabled track based robots featuring web-control and webcams, RAL-compatible infrastructure to provide the back-end linkage, portable netbook-type computers, and an arena space in which to hold the event.

Pedagogical Approach

In order to explore the pedagogical possibilities of the RAL technology for primary school education, the team of academics from USQ's Faculty of Education designed and implemented a pilot learning activity for a group of thirteen primary school children in collaboration with their colleagues in FoES. The design of this learning activity was informed by a constructivist approach to learning. This approach argues that children should be actively engaged in constructing their own knowledge and understanding through a variety of curriculum design and pedagogical approaches. According to this approach, teachers should select activities that build on prior experiences, that are seen by students to be purposeful and interesting, and that provide opportunities for children to learn how to do things, rather than simply to learn facts (Skamp, 2008). These dimensions were all incorporated into the design of the pilot learning activity.

Additionally, planning decisions were also informed by current curriculum priorities and pedagogical practices endorsed by the Queensland Studies Authority (QSA), which is the statutory body overseeing education in Queensland, Australia. The curriculum intent for this learning activity was based on the QSA documents for the Key Learning Area (KLA) of 'Technology'. One of the learning foci of this KLA, for year 7 students, is for students to "individually and collaboratively develop their ability to work technologically by generating, assessing and communicating design ideas and by selecting and using resources, tools and techniques, to design and make products to meet specifications" (QSA, 2007). These particular aspects of the curriculum – helping children develop their abilities to select and use resources to make productions to meet specifications, and so forth – are referred to elsewhere in the QSA curriculum documentation as 'Ways of Working' (QSA, 2007). These Ways of Working are quite similar in the curriculum documents in all other states of Australia (Fleer & Jane, 2011), thereby reflecting a common understanding of the importance of this aspect of children's learning about technology.

Whilst the above pedagogical frameworks are situated in the education discipline, clear links are evidenced between the productive pedagogies framework and Problem-Based Learning approach (Eggen & Kauchak, 2006) strongly established in engineering education discourse. This later approach is founded on two key assumptions about learning: that learning occurs in and through experience, and that learning happens by participating in a community of learning. One problem-based learning approach, inquiry-based learning, has been particularly influential in science and technology education (Llewellyn, 2001) and thus, cross disciplinary understanding is evidenced in the literature.

While the focus here is on student engagement and creating interest in engineering as a potential tertiary pathway, it is clear that such cross-disciplinary interaction has much scope for contributing to work in teacher professional development. For example, the first of the ten professional standards for Queensland teachers (QCT, 2006) requires teachers to design and implement "engaging and flexible" learning experiences. Thus, the Inquiry-based approach also has engaging and flexibility learning experiences as a central foundation and is able to provide a conduit for further cross-disciplinary work.

The Event

The RAL learning event was framed into particular stages, mirroring the intent of the TELSTAR acronym. The target audience for this event was children between the ages of seven and twelve, and in order to provide a more suitable series of phases, was re-structured to be:

1. Drive It; 2. Plan It; 3. Build It; 4. Test It; 5. Swap It; 6. Race It; 7. Reflect It

During the first stage, Drive It, participants were encouraged to engage with the task at hand, and develop awareness of the upcoming tasks and their procedural linkage. This approach was designed to assist in the developmental requirements of the participants providing them with a concrete experience of using the provided robotic equipment, before moving towards the more abstract concepts to follow.

In the second phase, Plan It, the participants were encouraged to take into account the limitations of the devices provided in the first stage, and, given a design brief, set about designing a race course for the robotic equipment given particular design characteristics. This racecourse (Build It) was then

constructed in the next stage, Make It. Participants were encouraged to test the design of their track (Test It) and to discuss any further design ideas, to ensure the viability of the race course produced.

The Swap It phase saw each group, in turn, leave the arena and, in a separate room, set about remotely navigating their way remotely around the other team's track (Race It). Here the children timed themselves for later comparisons. In this way they were able to collaboratively test their method and also begin to reflect collectively on potential modifications for the future. At the conclusion of the racing, the children participated in a recorded guided reflection (Reflect It) to provide insights into their learning.

From the teaching and learning perspective, the success of the day was the seamless interaction between the differing discipline groups and the ways in which future cross-disciplinary initiatives may be developed.

Results

During the event, video footage was gathered of all participants during the seven stages of the activity. Of particular note was the video gathered during the last stage (Reflect It). This consisted of a short forum reflecting on aspects of both the actual learning activity, and of participant's expectations, interactions, and own personal learning journey reflection.

Preliminary analysis of this data source has revealed several recurring themes.

Autonomy and motivation

- The challenge of the activity had appeal, as students had a level of autonomy that was different to that experienced in their usual schooling experiences. They commented that they felt 'in control', putting their ideas into practice and being able to push the boundaries of the rules by implementing "illegal" obstacles and the like.
- A competitive nature drove some students to engage in the activity more, while for others accurately manoeuvring the robot was more important than the time taken to complete the course. Therefore the activity had appeal for different learning motivations.

Collaboration and teamwork

- Younger students emphasized that they were engaged as they felt valued. It was also noted that the children found the activity appealing in terms of it being a new experience to work collaboratively with older peers.
- Multitasking and self organisation were also highlighted, where teams worked collaboratively to create task lists and assign members to those tasks. In this way they managed their own time and developed effective communication between the design and construction teams. This teamwork allowed them to quickly solve problems and individual's capacities were enhanced through the collective nature of the task.
- Team work was apparent in both the physical and remote aspects of the activity. Therefore it is possible to develop teamwork via the RAL system.

Communication

- Initially students were unable to articulate how their learning journey had progressed during the event, or their initial thoughts of the day's activities. This was relieved after peer pressure and forum engagement stress was reduced.

Problem solving

- The design aspects of the activities were considered a key highlight, where particular students would initiate changes to aspects of the design, with the concepts being refined by the group during discussions and construction stages.
- Students enjoyed driving the robots remotely, particularly as the complexity of the challenge increased when direct sight of the robot could not be achieved, and reliance was on the provided video camera feeds.
- Some students stated they learnt how to drive the vehicle through observation of others' mistakes, showing that view-only remote access experiments are valuable learning experiences.

- Students showed a better understanding of the science and technology surrounding the event by pushing the capability of the tracks and robots.

Learning transfer and reflection

- Students were able to relate their experience to real world situations.
- Students commented that they would have enjoyed a larger event using a larger track or even jousting between groups thereby illustrating their ability to extend their own learning.

Metacognitive awareness

- Students commented that it was a logical step to experiment with the real equipment before accessing and controlling it remotely, as they felt that they were more confident. They felt that the remote environment ‘made more sense’ because they had first-hand experience of the physical environment before having to remotely control the robots in a separate environment.
- Students commented on their enjoyment of engagement. They recognised that there was a reduction in their stress during the activity. The students commented that the lack of “hovering teachers” allowed them to develop a sense of ownership of the task and assisted them in remaining engaged and on-task for an extended period of time.
- Through reflection, the students demonstrated new understandings of skills required to successfully navigate the robots through the course. Therefore there was a degree of metacognitive awareness evidenced in the Reflect It stage. The students were also able to articulate a number of modifications and developments for the Robot RAL-ly building upon the learning that had occurred in this initial exposure to the RAL system.

Using a similar model of critical reflection as implemented with the students, the staff involved in the Robot RAL-ly also reflected on their own experience of participation. Through this collaborative reflection, again, key themes emerged.

The strength of cross-disciplinary interactions

- The experiments highlighted that mega-cognitive awareness appeared to be greater due to the perceived autonomy and sense of ownership of the experiment by the students. This perception led to a high level of sustained engagement and the establishment of ways of working collaboratively that valued each student’s contribution. Importantly, the staff members were seen as facilitators providing guidance rather than directing the learning experience and the students clearly understood that for technical guidance the engineering staff offered the ‘best’ advice, whereas the education staff members were accessed where the problems were more about the process. Therefore the marriage of technical and pedagogical expertise was beneficial to the students’ learning journeys.
- There was recognition that depending on the identified objectives, the learning outcomes could differ significantly, i.e. an education experiment from the engineering perspective, or an engineering experiment from an education perspective.
- The pedagogic scaffolding had a significant impact on the teamwork of the staff and was firmly embedded in a strengths-based discourse. Therefore, just as the student experience was heightened through a strong sense of autonomy and motivation, clearly the staff from each discipline area saw different value in the collaboration. Through the reflection, the engineers focused more on the future technical experimentation, modification and development of the RAL system, including control panels and the like, whereas the educators focused on the pedagogical implications for further experimentation and transfer of learning to classroom contexts. Teams actively identified and “owned” each individual robot. This “ownership” further served to increase participation.
- Through the education/engineering and surveying collaboration, clearly there is scope to promote engineering pathways at an early stage and thus build greater awareness of possible tertiary pathways into the field.

Efficiency and effectiveness of working remotely

- The time required to develop the activity, construct the robotic systems and develop the activity framework was significant initially, but there was recognition that efficiency over time was clearly achieved as once established, the experiment was available to a broad range of applications.

- Cross-disciplinary collaboration was easier due to the fact that, once established and the initial physical experimentation complete, there was scope for staff to continue to engage in collaborative reflection to further refine the learning experience through the application of multiple theoretical perspectives. This highlights the strength of collaboration in the staff learning journey.
- When working with children, hardware experiments appear to promote greater engagement over software-only experiments. The educators related this to the development of learning in terms of moving from the familiar to the unfamiliar and the concrete to the abstract. This understanding has implications for adult learners who may not have had initial exposure to particular physical learning experiences before being asked to participate in an abstract way. Therefore there is recognition of the need to incorporate this in the learning design regardless of discipline orientation.

Conclusions

The Robot RAL-ly event illustrates that a multi-disciplinary approach to learning and teaching, coupled with a strong collaboration between academics from different disciplines, assists in providing a more complete and sophisticated experience for students as well as for staff.

Through early exposure to experimentation of this nature, where autonomy and self-motivation are privileged, it becomes more plausible that children will develop a greater interest in engineering, science and mathematics and give consideration to these as potential career pathways.

In addition, engaging primary school children with engineering-related topics and themes through RAL, not only provides a valuable insight for engineering education, but also helps to offer a much more accessible engineering experience for potential future students. Because the RAL system permits external access to these activities, ongoing school and community engagement is possible. Through engaging with schools to extend the scope of RAL in science, technology, engineering and mathematics (STEM) fields, the university is able to establish enduring relationships within local regional and remote communities, thereby extending their reach and potential for influence.

This process showed that detailed attention to both the instructional and procedural methods employed in RAL activities is effective when pedagogical and technical expertise are married. The power of collective engagement of academics across disciplines strengthens the learning in terms of exposure to multiple perspectives and discourses that one might not ordinarily be exposed to. The paper concludes that, regardless of access and mode of study or discipline background, high quality interactions with peers in informal contexts can significantly contribute to the establishment of rich learning experiences. Importantly, this multi-disciplinary research team (authors) became more collectively mindful of one another's knowledge, skills and abilities, leading to a future focus that is strengths-based. A critically reflective process post-experiment produced a rich dialogue with the children, but equally led to further in-depth conversations between the academics, in terms of future pedagogical and technical developments. It is through this collaboration that the focus remains on trying to develop engineering skills and 'thinking like an engineer' in an informal learning context, rather than on focusing on math and science and stimulating interest in engineering through more structured, formal subject-based approaches to STEM.

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Acknowledgements

This work has been funded by USQ Learning and Teaching Performance Fund (LTPF) grants in 2010 and 2011.

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