Inception and Management of Remote Access Laboratory Projects

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***Abstract**: Practical experiments and laboratory exercises form an integral part of Engineering education programs and are a requirement for program accreditation. To provide off-campus (external/distance) students with practical learning experiences equivalent to that of their on-campus peers is both logistically difficult and resource intensive. A project was undertaken to provide all students with remote access to video-supported laboratory experimentation to allow students, regardless of location, to actively engage in contextual action-oriented learning and achieve course objectives with less emphasis on attending on-campus training sessions. The manner of design and implementation, and the management of research and scholarship, surrounding this project were informed by past experiences. This paper demonstrates the importance of consultation with all key stakeholders throughout the project life cycle and presents key components for the success of such projects. This approach is particularly relevant in situations where project management does not have line management over all members of the project team, often the case in university environments. The unique process followed by this Remote Access Laboratory implementation project represents a successful model that may well be followed by others.*

Introduction

Practical experiments and laboratory exercises form an integral part of programs in many Faculties at the University of Southern Queensland (USQ), a medium sized regional university in Australia. USQ has a unique student cohort with approximately 76% of students enrolled in a distance (external) mode and are located off-campus. Currently, external students are required to attend several concentrated sessions of laboratory work at residential schools to receive a learning experience equivalent to that of their on-campus peers. This can be a significant imposition for students with respect to time and finance. Practical activities are largely disjoint from lecture content, and there is little room to include practical activities in academic courses delivered in distance mode. The aim of the Remote Access Laboratory (RAL) project is to provide students with off-site access to practical and laboratory experiments. The provision of remote access to video-supported laboratory experimentation bridges the gap between real-life and virtual learning spaces. This allows students, regardless of location, to actively engage in contextual action-oriented learning and achieve course objectives with less emphasis on attending on-campus training sessions.

The Faculty of Engineering and Surveying (FoES) at USQ is a leading provider of engineering and surveying programs delivered via distance education in Australia and overseas. Approximately 2,500 students are currently studying in a wide range of professionally accredited undergraduate and postgraduate programs. Recently a number of initiatives have been undertaken surrounding the

development of operational methods to make laboratory experiments accessible remotely, and the implementation of associated systems to support this remote access. These individual activities led to a decision by Faculty management to make RAL a key strategic focus with a view towards university-wide deployment. Practice courses in FoES are discipline specific and often include activities from multiple academic courses. Remote access for practice courses is included in the FoES strategic plan with the outcomes to develop equivalent remotely accessible experiments/activities for practice courses; to provide access to selected experiments for schools and other interested community members; and to have the ability to share experiments with other Universities.

During 2009/2010 a system capable of providing remote access across the university was developed at FoES. The RAL is currently in its trial phase and most system-related technical aspects have been implemented, or will be finalised during Semester 2 2010. Two other Faculties at USQ will also trial RAL experiments in Semester 2 2010, using the systems and processes developed within FoES. It is planned that during 2010/2011 the RAL production system will be fully endorsed as a corporate system, available to all Faculties. The main focus of this paper is to outline and discuss the management methodology and strategic direction of the RAL initiative in FoES at USQ. The paper will also demonstrate the importance of consulting with all key stakeholders and presents the key factors to consider when implementing a remote access laboratory with an educational focus, which relies on the corporate ICT structure. The reported approach is particularly relevant in situations where the project management does not have line management over all members of the project team, often the case in universities.

Motivation

In accord with national priorities, the so called Bradley Report (Bradley et al. 2008) made recommendations for reforms to higher education to increase access to, and participation in, higher education. Accordingly, the Australian government has set policy to increase the proportion of 25 to 34 year olds with bachelor-level degree qualifications from 29% now to 40% by 2025 (Bradley et al. 2008). A key point to note is that this level of change will not come from growth in the existing markets for number of students wishing to complete tertiary education. To achieve the required growth, the higher education sector would need to grow in size and number beyond what is achievable or sustainable with government funded places. Rather, new markets must be catered for currently under-represented groups such as low socio-economic and remote students. In other words, it will probably be a structural change in the market that will effectively motivate students to enter higher education and ultimately cater for the necessary increase in student numbers.

This structural change may well result in a substantial increase in students studying by distance education, given the number of Universities worldwide that are increasingly moving to online delivery of programs. This shift of focus is facilitated by the speed and extent of the latest technological ICT advances. For example, the Australian National Broadband Network will provide high speed Internet to most Australian homes within the next eight years and is already being marketed as a vehicle for teaching innovations. From 2012, Federal Government funds will be provided to universities based on how many students each institution attracts – in essence a demand-driven model. From 2010, the government will raise the cap on over-enrolments from 5% to 10%, and from 2012, caps on student numbers will be scrapped altogether and universities will be allowed to take as many students as they deem profitable (DEEWR 2010). To successfully compete for these students, the universities will have to develop an even clearer understanding of students' issues when participating in higher education, and then develop strategies, systems and methods to address these issues.

USQ has traditionally been seen as being at the front line of distance education and has gained a reputation as a world leader in distance and online education. Whilst it is recognised that it is extremely difficult to enter the distance education market due to the substantial investment needed in infrastructure, training, and of course the development of essential corporate knowledge, one of the best ways to retain market share post-2012 and deregulation is to ensure USQ remains at the cutting edge of online and distance education. RAL will benefit students in many ways such as increasing flexibility of program delivery, providing a cost and time effective service to students, linking students to allow them to co-create knowledge and to foster collaboration, enhancing the connection between

practical and theoretical knowledge, and increasing availability of laboratory equipment. This is particularly relevant in the USQ and FoES context of distance and online education.

Remote Access

Technology to enable remote labs has been discussed in the research community for more than a decade (e.g. Aktan, Bohus, Crowl, & Shor, 1996). Many published activities focus on individual solutions to specific experiments. A number of initiatives address the problem on a larger scale and have developed infrastructure solutions comparable to USQ's initiative (Lowe D. , Murray, Lindsay, & Liu, 2009). The Australian Labshare project (e.g. Lowe, et al., 2009) aim is "to create a (nationally) shared network of remote laboratories that results in some combination of: higher quality labs; greater student flexibility; improved educational outcomes; improved financial sustainability; enhanced scalability in terms of coping with student loads; and are developed and run by those with the appropriate expertise". Other high profile solutions include the MIT iLab project (Harward, et al., 2008) that has developed a software toolkit to enable and promote the sharing of laboratories via the Internet. An analysis of FoES requirements and existing systems showed that none of the existing solutions were able to address all the requirements. To use remote laboratories and provide activities online, three key challenges have to be addressed:

- Learning objectives have to be identified and the learning activities have to be designed and developed.
- An apparatus, i.e. an experiment or rig, has to be designed and developed to undertake the learning activity. Experiments have to be automated and controllable via computers. Most initiatives focus on hardware experiments only, whereas the USQ project makes no distinction between software and hardware experiments.
- Users have to gain access to computers that control experiments. Scheduling, authentication and mediation is required at this level.

The focus of the USQ RAL project is to provide hardware and software infrastructure to address access and enable individual educators to concentrate on the first two issues. On a technical level, the USQ RAL system consists of two key components. The first component includes infrastructure providing remote desktop access to computers driving physical experiments and virtual machines that host software experiments. The second component is a web-based management system that integrates with the learning management system. The student's interaction with the management system is limited to book time to interact with activities. The web interface is based on php/mysql and access uses Sun Global Desktop Infrastructure. One key difference between this project and other published projects (e.g. Lowe, et al., 2009) is that USQ RAL includes hardware as well as software experiments and seamless integration with the current learning management system, Moodle.

Primary considerations for designing laboratory activities are the learning objectives that they aim to achieve. ABET, inc. has formulated a list of thirteen potential learning outcomes gained from laboratories in engineering education (Feisal & Peterson, 2002). Pedagogical aspects of RAL have received growing attention by the research community (e.g. Lindsay, 2005); however, major aspects remain unclear. For example, Trevelyan (2004) asserts that learning objectives and outcomes do not significantly differ between proximal and remote laboratories. In contrast, Lindsay (2005) suggests that different learning outcomes result from different access modes. Lindsay et al. (2007) found that students are affected by the fact that remote laboratories can force them into the independent practice phase of the learning cycle. In the absence of instructors it is therefore important that their learning experience is not impeded by performance of the system. Ultimately, the effectiveness of remote laboratories depends on the extent to which they help students to attain course and program objectives (Arango, Chang, Esche, & Chassapis, 2007). It is therefore important to keep pedagogic issues in mind and focus on outcomes rather than clever technical solutions.

An important part of the USQ-FoES project is the strong focus on the scholarship of learning and teaching in the project quality cycle in parallel to system development. A research framework and methodology have been developed; and a comprehensive literature review has been undertaken that is available to all academics using RAL.

Methodology

Anecdotal evidence suggests that academic ICT projects at Universities are often undertaken without the support of, and indeed sometime against opposition from, ICT departments. The RAL project at USQ has taken a different approach and the project team worked in close collaboration with USQ's Division of ICT to enable RAL access for all students. The USQ has a well established project management methodology that provides a structured approach to projects with ICT components. These procedures are based on well established and accepted Government project management guidelines. The procedure involves developing and approving a project mandate and a project initiation document. This section introduces the management methodology in general terms and discusses specifics of the RAL project.

Project Mandate

The Project Mandate is the initial formal project document, which captures information that is external to the particular ICT-related project. It establishes the terms of reference and is used to commence the project. It outlines the problem to be solved, objectives, scope and constraints. The completed mandate is rated by a business analyst from ICT and the University ICT Strategy Committee. The members of the ICT Strategy Committee are senior executives at the University level who approve or reject the mandate. If it is approved, this signals the next phase of the project which is to develop the Project Initiation Document (PID) that captures project details. The PID is discussed in the following section.

The goal of the RAL initiative was to seamlessly integrate experiments with the LMS Moodle. Experiment access, authentication, access management and booking were to be developed and maintained by ICT. The project outcome was to be a platform that can be used across the University. It was envisioned that individual faculties develop, maintain and manage their own experiments. The main project objective was to provide off-site access to hardware and software experiments for USQ students, local and remote schools, other Universities as well as for community engagement with the general public. The scope was identified to include all ICT technologies that are necessary to enable experiment control by external student, including authentication, mediation and remote desktop access. Three stages with specific deliverables were identified to ensure rapid deployment and usability with added functionality in subsequent stages. The following project stakeholders were identified: faculty management as the project initiator; students as system users to access experiments; lecturers as system users to setup and manage experiments; Division of ICT as service implementers and service providers for USQ wide applications; other faculties, linked secondary schools and the general public as potential system users. Students were identified as the key beneficiaries of this project as it will provide them with great flexibility, reduce the number times they have to travel to Toowoomba and improve teaching and learning outcomes.

Project Initiation Document

The Project Initiation Document defines the project in greater detail and collects all information that is required to start a project. It begins with a general outline of the problem and provides details on major subsystems, organisation structure, communication plan, quality plan, project tolerances and controls.

The RAL project has been divided into three stages: Initial system development and testing, to implement basic functionality and provide proof of concept; advanced feature development and testing this includes most features and provides trial environment that is used with classes; and final deployment and testing, i.e. deliver a production system. Subsystems were identified as deliverables and assigned to stages. Key project assumptions were stated including major milestones, general funding and risk arrangements. The project was funded by the FoES, mainly supporting web interface development and system administration. In addition, part of the development cost has been provided by ICT in-kind. Cost for personal on the faculty level, e.g. for project management, were additional in-kind contributions. Software licensing and infrastructure cost for the production system was not part of this project.

The project organisation structure consisted of a project board with members from ICT and faculty, headed by the Dean of FoES. A project manager and a project group undertook development. The team involved ICT and Faculty staff. The following communication plan was implemented: The

project board met monthly in the initial phase and bi-monthly during later stages of the project. Project related documentation was made available to all project members via SharePoint. Formal project status reports were provided to the ICT Strategy Committee by the project executive on a bi-monthly basis. These progress reports provided an opportunity to highlight areas that required urgent attention to senior management. The project team met weekly. The project quality plan highlighted quality expectations such as transparent and seamless access to experiments without intermediate screens.

Lessons Learned

In contrast academics tend to look for cutting edge solutions that are unique, and thus more publishable, while ICT departments look for proven solutions that are reliable and can be bought off-the-shelf. In the end the compromise solutions were reached where all parties largely achieved their desired outcomes. The combination of off-the-shelf and custom solution was necessary as none of the existing system addressed all requirements. At the beginning it was difficult to work together as people tended to follow personal agendas and were reluctant to cooperate. Another problem was the complexity of the project as it required the expertise of several ICT departments including network, desktop support, security, web development and infrastructure. Issues were amplified by different project management methods used by various groups. The approach was to solve issues on the grassroots level directly with programmers and administrators. However, on the occasions when an impasse was reached, bottom-up, top-down intervention was required and top level management intervention was necessary a number of times. The degree of support from senior management had a critical influence on the project success – as identified by (Meredith & Mantel, 1995).

System design was not completed at the initial stage of the project. A formal requirements analysis would have been helpful as initial specifications where dominated by individual needs of authors. Some specifications were made in real time. These issues are generally difficult to address as requirements evolved during the development. A formal requirements analysis would have required another project cycle resulting in additional time and costs. A common SharePoint area was established; however, configuration management was left to the individual ICT departments. Documentation standards were inconsistent and that caused some minor problems when a key contributor left the project. For future project documentation standards, configuration management and issues tracking should be enforced from the onset.

The project team did not have access to all the management tools to fully motivate the project team. From the Faculty's perspective the best that could be offered was a small workload allocation to allow staff to dedicate expertise to the project. This was insufficient to cover the work commitment required by the individuals. No additional remuneration was offered and it was expected that the team would put in the extra effort because while it was beneficial to the Faculty, success would also directly benefit their own academic careers. From the perspective of ICT staff, since the Faculty did not have line management control over any of these team members, the ability to offer motivational incentives was even more difficult. The best that could be offered to these team members was a few free lunches and the opportunity, and associated kudos, to work on a cutting edge project that ultimately could be seen as a symbol of technological advancement at the university. Consistent with Herzberg, Mausner, and Snyderma (2004) though, this proved to be adequate.

It was not always easy to ensure that the quality and integrity of the project was preserved given the sometimes conflicting demands of key stakeholders and others who justifiably had an interest in the outcomes of the project. However, one thing that was strongly reinforced was to never allow senior management to be taken unawares with bad news if you wish to retain their support.

Conclusion

The key infrastructure that has been successfully developed and deployed by USQ-FoES as part of the RAL initiative provides a strong platform for engagement with stakeholders, such as, other Universities, TAFE and VET sector, local and remote schools, industry, and the general community. The Faculty believes that RAL is essential to support outreach programs to remote schools in western towns such as Roma and St George. It is also seen as a tool to develop programs that can be used to

target and assist students from low socioeconomic backgrounds. The RAL initiative will help to guarantee parity of student experience, regardless of geographic location.

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