Reflecting Professional Reality in Remote Laboratory Experiences

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Abstract— **An ABET Colloquy in 2002 described a core set of thirteen objectives for Engineering laboratories. An implicit theme amongst these objectives is the development of an understanding of real-world Engineering. Often this will have occurred though exposure to commercial tools, equipment and processes, as well as realistic problems. Whilst remotely accessible laboratory infrastructure is becoming more common, the question of how these affect student perceptions of reality is salient - a question which has barely been considered in the literature. The only related work is some discussion on the fidelity and/or authenticity of the experience. In this paper we discuss these issues. In particular, we consider the factors within a laboratory experience which potentially affect the students' interpretation of the industrial or professional "reality" of the experience. We then discuss whether remote laboratories help or hinder in the development of this professional reality.**

Index Terms—**Laboratory, remote, professional, practice, experience.**

I. INTRODUCTION

Laboratory experiences have long been considered a core component of technical degree programs – particularly in engineering and the applied sciences. Despite this, there has been surprisingly little consideration given to why laboratories are utilised and what are the intended learning outcomes for students. An ABET Colloquy in 2002, described in (Feisel and Rosa, 2005), described a core set of thirteen objectives for Engineering laboratories. These related to the development of abilities such as applying appropriate instrumentation and tools, identifying the strengths and limitations of theoretical models, and the ability to collect, analyze, and interpret data, as well as many others (see Addendum 1 for the full list of objectives). While not addressed explicitly, an implicit theme amongst a number of these objectives is the development of an understanding of either real-world Engineering, or the way in which specific skills and knowledge relates to professional practice. This was well articulated in earlier work (Panel on Undergraduate Engineering Education, 1986) which considered the role of laboratory instruction, and quoted work by Ernst (1983), stating:

> *The undergraduate student should become an experimenter in the laboratory, which 'should provide him with the basic tools for experimentation, just as the engineering sciences provide him with the basic tools for analysis' Ernst, 1983b:4~. It is a place to learn new and developing subject matter as well as insight and understanding of the real world of the engineer. Such insights include model identification, validation and limitations of assumptions, prediction of the performance of complex systems, testing and compliance with specifications, and an exploration for new fundamental information.*

Of particular salience is the articulated need to support students in gaining insights into the "real world" (presumably, in this context, "real world" refers to the domain of professional practice within which the students' are likely to be applying their skills).

Once again, there has been remarkably little consideration given within the literature to how laboratories support this engagement with the realities of professional practice. Anecdotally, this will often have occurred through aspects such as:

- Exposure to tools, equipment, instrumentation, etc. which is either used in professional contexts, or which is indicative of commercial equipment;
- Utilisation of skills (both technical and prosess-management orientated) which are explicitly relevant within real-world settings;
- Laboratory exercises which are representative of realistic problems and behaviours or which highlight relevant elements of these problems;

While these may be objectives, it is unclear what elements of the design of laboratories make the professional reality of the laboratory experience self-evident to students. These issues become even more salient in the context of the increasing interest in the use of remote laboratories, where there is an additional and obvious level of disconnect between the student and the laboratory, and hence the student and their connection to the professional practice elements of those laboratories. If we are to design remote laboratories effectively, we need to understand this relationship to reality and how the design of the laboratory mediates this relationship.

II. BACKGROUND: REMOTE LABS

As ICT infrastructure has become increasingly prevalent in most areas of the world, there has been a steady increase in the development of remote laboratories over the past few years (Corter and Nickerson, 2007). Figure 1 is an example of a current remote laboratory facility – that which we have developed, and are continuing to refine, in the Faculty of Engineering at the University of Technology, Sydney. Figure 2 shows a typical interface for a single remotely access laboratory

Figure 1: UTS Remote Laboratory Facility

experiment – in this case an introductory undergraduate civil engineering laboratory exercise investigating beam deflection under loading.

There are several motivating factors supporting the development of remote laboratories, including cost, security, reliability and convenience (Murray and Lasky, 2006). Operating costs can be reduced through saving in physical space and with the equipment and apparatus being held in a physically secure environment with tightly constrained access which limits either intentional or unintentional misuse. Greater flexibility of access can be provided to students (potentially providing a richer engagement than might occur in limited and controlled direct access to physical infrastructure). They also offer a capability of inter-collegial sharing of expensive laboratory infrastructure and resources (it is an interesting exercise to consider current utilisation levels of much existing Engineering laboratory infrastructure). Partly as a consequence of the above issues, it also becomes possible to develop and make available more elaborate, expensive and/or delicate experiments. This in turn makes possible student exposure to systems that might not have otherwise been afforded them (potentially more commercially realistic and/or relevant). The result is that when viewed on a macro scale, more rather than less experimentation by students becomes possible. Additionally, the convenience and flexibility of being able to complete laboratory experiments remotely tends to fit well within the complex lifestyle of the contemporary undergraduate student profiles. The potential benefits to students are enormous and profound, but it requires a global view if it is to be realised.

The earlier era of remote laboratory development saw most effort directed at technical evolution – preoccupations included experimenting with technologies for real-time audio and video streaming in an effort to overcome bandwidth limitations whilst ensuring service quality, and dealing successfully with the arbitration of multiple simultaneous connections to shared online laboratory apparatus and equipment. To a significant extent, many of these issues have been successfully overcome. Continuous, reliable and high quality services have been maintained for much of the past decade. This progress has resulted in a shift in the focus of development effort away from technical refinement. Recent trends focus upon enriching the nature of the student interaction (for example, including support for student-student collaboration and student-teacher interaction). In parallel there have been moves towards a clearer understanding of the pedagogical aspects related to conducting laboratory work remotely and indeed a more reflective consideration

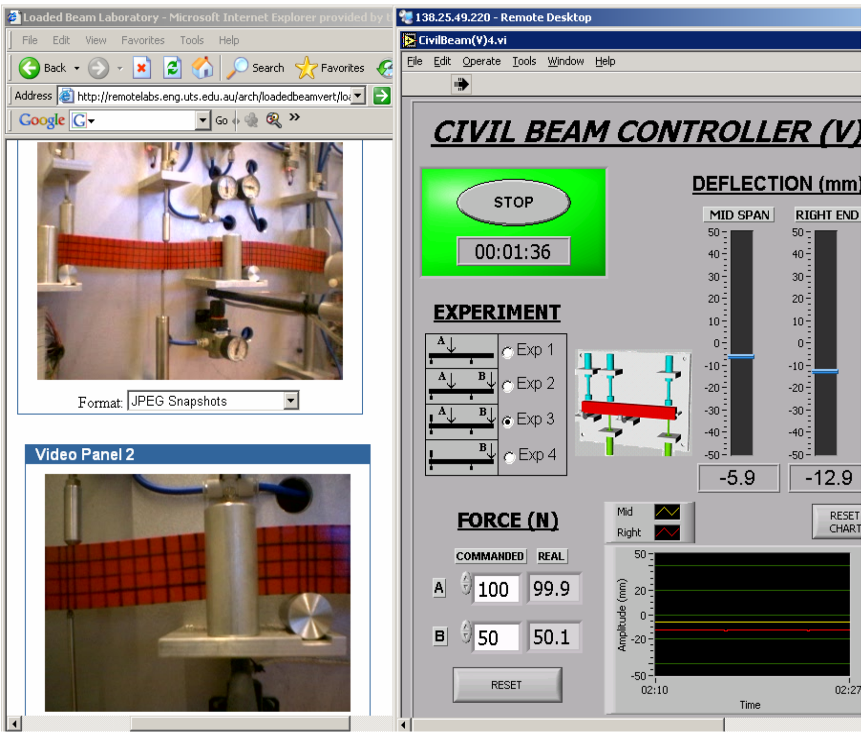

Figure 2: Student Interface to the Beam Deflection Remote Laboratory

of the laboratory learning context in general (both conventional laboratories where students are proximate to the equipment they are using as well as remote laboratories) and the place of experiment simulation (Lindsay and Good, 2005).

III. ENGAGING WITH REALITY

As this remote laboratory infrastructure becomes more prevalent, it raises questions on the impact on students' insight and understanding of the real-world nature of the practice of their profession. As discussed above, this is an area which has barely been considered for traditional proximal laboratories, let alone remote laboratories.

One area of existing work which does have some relevance, is discussion on the fidelity and/or authenticity of the laboratory experience. In particular, Aldrich (2004) discussed simulations and the impact of the fidelity of the simulation. Interestingly, it was noted that in some circumstances an overly-realistic simulation may prove to be distracting to students and inhibit the learning process rather than enhancing it.

Our own work (Linday et al, 2008) has extended this and considered the investigation of issues such as the notion of "establishment reality" versus "maintenance reality". Establishment reality refers to the threshold for establishing a perception of reality when students first encounter a remote experiment (that is, to what extent do the students believe they're interacting with real apparatus). This is related to the knowledge required to build a mental model of the experiment. Conversely, maintenance reality refers to the (lower) level of detail required to maintain the perception of reality once a student has developed an engagement with the experiment.

It is important to consider which reality is being established or maintained. Many simulation- or remote access laboratories focus upon the extent to which students perceive this as 'real' rather than artificial – rather than the extent to which it reflect commercial reality. In other words, it is important to distinguish between a constrained academic reality and a broad contextual professional reality.

If we are to develop remote laboratory experiences which support students in constructing an understanding of professional engineering, then we need to consider what is required for the establishment and then maintenance of a professional practice reality. There is no value in making a remote access laboratory equivalent to its face-to-face predecessor if the industrial reality has since moved on. In fact, it could conceivably become counter-productive in the sense that students might tend toward a disengaged mindset if they consider the apparatus antiquated.

As part of considering students' utilization of our remote laboratories we undertook a series of surveys of students' reactions to the remote laboratories – and in particular a laboratory experiment involving the employment of a Programmable Logic Controller (PLC) to control a pair of pneumatically driven pistons. These are of the type that in a production environment would be used to push objects onto a conveyor belt for example. The surveys included an evaluation of students' perceptions of whether they were controlling real equipment. Of 39 responses, 29 responded "yes" and 7 responded "no". Interestingly, a number of those who responded "yes" qualified their response in various ways, including indicating that the sense of realism depended upon:

- if they had the right PLC;
- if the network had not too much lag/latency.

The most significant response, in terms of perceptions of reality, however related to the existence of a live video feed of the equipment, and the extent to which this made visible the "reality" of the experience – that being, an immediate contributer to "establishment reality".

Similarly, when asked if using the remote laboratory was more, or less, beneficial than a simulation 53% of respondents indicated more beneficial and only 7% indicated less beneficial. Of those who felt that it was more beneficial, a number of responses indicated that this was so because having the exposure to remote technology was more real – both in conducting the experiment and also more like what they would face in the future. Mentioned also was the fact that having something physically working felt more satisfying (in comparison to simulations which "just don't feel right"), and it was more exciting so they felt more motivated. In other words, a sense of "feeling right" was considered a significant positive factor.

Before we can consider the implications of these comments on connecting remote laboratories to professional reality, we need to take a step back. In particular, we need consider the factors within a laboratory experience which potentially affect the students' interpretation of the industrial or "professional reality" of the experience, as distinct from the more usual consideration of the "academic reality" of the experience.

- Professional setting: the extent to which the laboratory infrastructure will be perceived by the students as indicative of a professional practice setting. This will require the inclusion, within the student interface, of the contextual elements which may be seen as extraneous to the experiment, but which position the experiment within a broader setting. For example, a "beam deformation" experiment may position the beam within the context of a support for a broader structure. This is a quantity which theoretically should translate seamlessly from a similarly configured experiment in a proximate laboratory.
- Real-world complexity: the extent to which the experiment includes an opportunity for the student to appreciate the complexity associated with actual practice. This need not include additional experimental complexity, but rather might involve time limitations, team and communication requirements, limitations on cost or materials etc.
- Delegation of control over the focus and purpose of the experiment to the student (Edward, 2002). By allowing students to take greater control over the progress of the experiment, they are able to explore various possibilities, and hence to make stronger connections to reality.
- Connections to real industrial problems. Drake et al. (1994) describe experiments in which an explicit link was made to real industrial problems – including an overall duration for completion of

more than a year. This led to a much stronger student sense of accomplishment, but would be likely to present logistical challenges.

IV. Conclusions and Further Work

With remote laboratories reinforcing the progression of technical and professional formation of engineering students, the sponsors of remote laboratories are obliged to be sensitive to both technical and professional contexts of student learning. The level of student engagement with a laboratory exercise is critical in achieving these outcomes – not just in the initial Establishment Reality phase of conducting an experiment, but in the sustained requirement of the Maintenance Reality phase. Establishment reality is not difficult to achieve if the students can be permitted to see the remotely accessible apparatus for themselves, for example. Maintenance reality depends more upon constructing a convincing scenario that envelopes an experiment – that is, something which would appear to be a realistic proposition for a professional engineer.

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Addendum 1

The following is extracted from (Feisel and Rosa, 2005).

By completing the laboratories in the engineering undergraduate curriculum, you will be able to....

Objective 1: Instrumentation. Apply appropriate sensors, instrumentation, and/ or software tools to make measurements of physical quantities.

Objective 2: Models. Identify the strengths and limitations of theoretical models as predictors of real-world behaviors. This may include evaluating whether a theory adequately describes a physical event and establishing or validating a relationship between measured data and underlying physical principles.

Objective 3: Experiment. Devise an experimental approach, specify appropriate equipment and procedures, implement these procedures, and interpret the resulting data to characterize an engineering material, component, or system.

Objective 4: Data Analysis. Demonstrate the ability to collect, analyze, and interpret data, and to form and support conclusions. Make order of magnitude judgments and use measurement unit systems and conversions.

Objective 5: Design. Design, build, or assemble a part, product, or system, including using specific methodologies, equipment, or materials; meeting client requirements; developing system specifications from requirements; and testing and debugging a prototype, system, or process using appropriate tools to satisfy requirements.

Objective 6: Learn from Failure. Identify unsuccessful outcomes due to faulty equipment, parts, code, construction, process, or design, and then re-engineer effective solutions.

Objective 7: Creativity. Demonstrate appropriate levels of independent thought, creativity, and capability in real-world problem solving.

Objective 8: Psychomotor. Demonstrate competence in selection, modification, and operation of appropriate engineering tools and resources.

Objective 9: Safety. Identify health, safety, and environmental issues related to technological processes and activities, and deal with them responsibly.

Objective 10: Communication. Communicate effectively about laboratory work with a specific audience, both orally and in writing, at levels ranging from executive summaries to comprehensive technical reports.

Objective 11: Teamwork. Work effectively in teams, including structure individual and joint accountability; assign roles, responsibilities, and tasks; monitor progress; meet deadlines; and integrate individual contributions into a final deliverable.

Objective 12: Ethics in the Laboratory. Behave with highest ethical standards, including reporting information objectively and interacting with integrity.

Objective 13: Sensory Awareness. Use the human senses to gather information and to make sound engineering judgments in formulating conclusions about real-world problems.

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