A Toolkit for Remote Laboratory Design & Development

Abstract—Remote laboratories are an increasingly prevalent instructional tool for undergraduate engineering laboratory classes. This increased prevalence brings with it a need to change the model of how remote laboratories are developed. The earlier remote laboratories were developed by individual academics combining their discipline-specific skills with their own ability to implement remote operation. This “cottage industry” model allows for significant local innovation; however it does not support widespread or sustainable implementation of remote laboratories. In order to make remote laboratories a mainstream technology, it is essential that potential academic users are well informed and well supported in considering remote laboratories. There are some well-developed and well-established systems for controlling equipment remotely; what has been missing has been the organizational scaffolding to facilitate the engagement of academics. This paper reports on a resource kit developed by the Australian Labshare project that provides this assistance. This resource kit is intended to provide academics with the resources, information and tools that they need to get started with remote laboratories – building them, using them, and understanding their educational outcomes.

I. INTRODUCTION

In recent years remote laboratories have transitioned into a maturing technology [1-4]. The benefits of distance education have been documented and reviewed and the specific role of remote laboratories in engineering education has been clearly defined.

While remote labs were originally presented as the second best option to a hands-on lab [5] it has since been shown that each access mode provides a different set of learning outcomes [6]. Additionally, remote laboratories have been shown to provide significant benefits compared to traditional hands on laboratories. Examples include increased time for student access to equipment, resource sharing between institutions to offset costs and a more versatile range of experimentation due to the mitigation of safety issues [7].

The focus of remote laboratory development is now moving towards more sustainable models. Rather than individual academics custom building equipment for their specialized subjects, remote laboratory development is increasingly being carried out by multi-institution consortia, such as iLabs [8], LiLa [3], VISIR [2] and Labshare [4]. These groups allow academics considering remote laboratories to take advantage of pre-existing tools to implement their experiments, rather than having to begin from scratch.

Numerous papers have attempted to introduce a defining standard in fields ranging from system architecture to software development. The most successful of these have occurred due to the combined efforts of several institutions. One of the goals of the Australian Labshare project [4] is to implement a similar strategy, while also confronting a number of other challenges such as the pooling of resources, the issue of accreditation as it pertains to courses involving remote laboratories and making remote laboratories more readily available to more than specialized faculty.

In order to inform interested faculty about remote laboratories and to facilitate their involvement in the Labshare project, the Labshare toolkit was developed. The toolkit offers materials in support of remote laboratory technical development, pedagogical efficacy and organizational sustainability. This paper concentrates on the pedagogically-oriented components, which are freely accessible via the Labshare website (http://www.labshare.edu.au/) and currently include:

- The Labshare FAQ
- A Glossary of terms
- A Literature Review of remote laboratories, including an endnote library containing over 380 remote laboratory references and a ranking of the most cited papers
- A framework for determining rig suitability
- A snapshot of the current catalogue of available experiments
- An Accreditation Commentary that details how remote laboratories can contribute to meeting the ABET and EA accreditation criteria
- Sample lesson plans for the available rigs, including templates for layout
- Sample evaluation questions, covering both the development and implementation processes as well as the student usage experience

With access to the toolkit faculty will be able to familiarize themselves with the development process of remote laboratories, acquaint themselves with the Labshare project and access the tools required to build and implement their own remote laboratory.

II. THE LABSHARE FAQ

When initially being confronted with the idea of remote laboratories, there are numerous questions that are inev-
typically asked, some more immediately than others. While dealing with individual colleagues it is possible to inform faculty on a case by case basis, however as the scale of the collaborations expand this becomes less practical. A listing of frequently asked questions enables this information to be accessed on demand. The FAQ, which has been evolving over approximately four years, currently includes information regarding the benefits of remote laboratories compared to other laboratory types, the advantages to staff and institutions, the purpose of LabShare and how to get involved. As remote laboratories mature and the scope of development shifts, the focus of questions will be updated to address the anticipated problems of the time. Some sample questions from Labshare’s FAQ documentation are illustrated in figure 1.

III. THE LABSHARE GLOSSARY

A typical remote laboratory implementation requires a range of elements in order to be successful. The purpose of the glossary is to standardize the terms, and define the meanings, used to describe these recurring elements. A sample of Labshare’s glossary is illustrated in figure 2.

Previously remote laboratory developers have worked in independent groups, developing their own prescribed terminology to describe important concepts. Given this trend it became prudent to develop and maintain a database that specifies the terminology used within the Labshare consortium. Currently included terms focus on describing the remote lab’s physical rig, pedagogy, stakeholders and software.

An additional benefit of the glossary is that it enables faculty unfamiliar with remote laboratory terminology to adequately interpret the other information provided in the Labshare toolkit. As the toolkit expands over time to include a greater depth of information, the glossary will also continue to evolve, keeping Labshare members up to date in the developments of remote laboratories.

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**Figure 1. Example questions from Labshare’s FAQ**
IV. LITERATURE REVIEW

Remote laboratories first appeared in the Engineering Education literature in the mid 1990’s [9]; since that time there have been some well-known and well-understood themes that have emerged in the field. The toolkit seeks to provide developers with access to this literature, supporting them both during their early orientation to remote laboratories, and as they seek to expand their expertise.

Labshare’s current endnote library includes over 380 references from a wide variety of authors. This comprehensive index of the field is intended to assist faculty in exploring aspects of the field of remote laboratories in great depth by guiding them to relevant articles within the field.

Labshare has comprised listings of “Top Ten” papers for categories that will inform faculty of the trend in development for remote laboratories. These listings include informative papers for introducing faculty with no remote laboratory experience and listings of the most cited papers to date. When viewed in their entirety the introductory papers provide a sufficient picture of the role of remote laboratories in engineering education. Information provided includes, but is not limited to, prominent remote laboratory experience and listings of the most cited papers to date. Given the nature of remote labs, such as round the clock accessibility and repeated use, recognizable forms of lab equipment are of a less compatible nature than others. The appropriateness of lab equipment includes the cost to run, if consumables are used regularly, the reproducibility of results and the availability of equipment.

The characteristics of the student body making use of the lab will also play a vital role in assessing the suitability of a remote lab conversion. Ease of internet access, geographical distribution and the student to rig ratio are

V. A FRAMEWORK FOR DETERMINING RIG SUITABILITY

Before commencing a remote laboratory implementation, it is essential to determine whether the laboratory experience is in fact suitable for remote operation. This segment of the toolkit provides the user with a framework to assess this suitability. Factors taken into account by the framework include learning factors, cohort factors and equipment factors. A segment of Labshare’s framework document is showcased in figure 3.

There are various laboratory characteristics which encourage or discourage a conversion to enable remote access. These include information flow, measurement methods, collaborative, supervisory, accessibility and health and safety.

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The characteristics of the student body making use of the lab will also play a vital role in assessing the suitability of a remote lab conversion. Ease of internet access, geographical distribution and the student to rig ratio are
examples of factors that influence the appropriateness of a hands-on to remote lab conversion.

This part of the toolkit is substantially based upon [10].

VI. A SNAPSHOT OF THE LABSHARE CATALOGUE

In order to keep track of the remote laboratories that are under development, as well as those already available, a catalogue that showcases the rigs that comprise the Labshare network is available online. Each listing includes detailed information including availability, access modes, rig type, target discipline and year, a description of the experiment and the provider institution and academics. An example of a remote laboratory included in Labshare’s catalogue is shown in figure 4.

Currently the Labshare toolkit includes a snapshot of the catalogue to enable distribution in an offline capacity. It is planned to convert the catalogue into an online searchable database.

VII. ACCREDITATION COMMENTARY

One of the most commonly expressed fears regarding remote laboratories is whether accreditation bodies will consider them to be acceptable. The toolkit addresses these concerns by providing a guide to incorporating remote laboratories into the responses to the accreditation criteria, both for ABET and for Engineers Australia.

Accreditation reviews, of relatively new developed technologies, is of particular interest to academics interested in developing and implementing their own courses. Without the support of the wider community, it is potentially difficult to cater a lesson plan to specific criteria that accreditation bodies require. However given the support Labshare provides, in the form of an accreditation commentary, new members are able to start developing immediately.

Each of the accreditation criteria are addressed in turn and are categorized as directly relevant, marginally relevant or irrelevant to remote laboratories. For each criterion that is considered relevant, guidance is given for explaining how remote laboratories contribute to the outcomes of the overall degree program, and how they can be implemented without jeopardizing the overall quality of the program’s graduates.

6.11 Mapping, Localisation and Obstacle avoidance

**Audience:** 2nd to final year university students

**Discipline:** Mechanical Engineering, Mechatronics Engineering

**Status:** Available

**Provider Institution:** UTS

**Lesson Author:** Dr Sarath Kodagoda

**Abstract:** Using Bayers rule and the onboard sensors students have to program the robot to carry out mapping then localise the robot on the map using particle filters and Kalman filtering. The robot then has to patrol the generated map avoiding any present obstacles using path planning.
A well-designed and well-implemented remote laboratory may in fact be more educationally beneficial for students than the traditional face to face laboratory it is supplementing or replacing. The laboratory needs to be considered in the context of the overall degree program, and presented to the accreditation panel as part of the overall education of the engineering students. This part of the toolkit provides advice on how best to do this presentation.

VIII. LESSON PLANS

The lesson plan portion of the toolkit provides a standardized template that can be used for a remote laboratory setup. Given the essential focus of ensuring students a high quality learning experience, the educational design of laboratory classes is considered an exceptionally important part of participating in Labshare.

The current version of the template is considered comprehensive enough to put into practice and as such has been used to create a variety of lesson plans for existing laboratories. Key components of the lesson plan include an overview, goals, prerequisites, rig information and assessment information.

To ensure the quality of lessons provided by Labshare, lesson templates require a significant investment of time and research to complete. Therefore in order to assist users in the task, exemplar lesson plans are provided. Currently examples include loaded structural beam, PLC programming, determination of gravitation acceleration and structural visualization remote laboratories. As the lesson plans becomes more widely accessed additional assistance will be provided if necessary.

IX. EVALUATION QUESTIONS

When implementing any major change, it is important to evaluate its effectiveness. Labshare implementation covers a range of different changes, and as such it is important to have access to a range of evaluation tools. The Labshare toolkit contains instruments to survey the development, deployment and learning attributes of potential remote laboratory setups. Each survey poses a series of questions, which enables an analysis of components that will make successful implementation of a remote lab rig more likely. Also included in the toolkit are approximately 150 additional questions, which will allow users to build their own assessment tools as required. Example questions from documentation provided in Labshare’s toolkit are shown in figure 5.

X. ONGOING DEVELOPMENT

The Labshare project is currently carrying out evaluation and sharing trials. Throughout the second semester of 2010 and first semester 2011, a total of over four thousand students from approximately nine institutions will be using Labshare-administered remotely accessible experiments in support of their learning. This undertaking has been carefully planned to ensure that participation in the trials incorporates not just use of some experimental apparatus over the Internet, but that the whole user experience is carefully assessed. Student users are requested to complete an online survey after finishing their learning exercise and the teaching staff are asked to provide a summary of their impressions of the experience. It is anticipated that the large volume of data gathered throughout this exercise will present several avenues of continued development which will strengthen the toolkit considerably.

XI. CONCLUSION

By providing the presented toolkit to new, existing and potential members of the Labshare consortium, the information and planning required to produce high quality remote laboratories has become freely available. Not only does this present an easily accessible repository to faculty current specializing in remote laboratories, it also paves the way for faculty unfamiliar with internet-based control to become involved in the development process. By expanding the pool of potential participants actively involved in the development process, benefits such as the pooling of resources and increasing student accessibility to a diverse range of experimentation will become more fully realized.

REFERENCES

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