

# LabShare: Towards a National Approach to Laboratory Sharing

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***Abstract:** Conventional undergraduate engineering laboratories are valuable in terms of their contributions to students learning but are costly to develop and maintain and have extremely low utilisation rates. These issues can be addressed through cross-institutional sharing of laboratories; however this is limited by the overarching requirement that students are located in a centrally located laboratory. In this paper we describe the nature of the challenges and the potential benefits that can be achieved if a solution can be found. A possible solution is the use of remote laboratories that can be accessed across the internet with a suitable model for laboratory sharing that promotes both institutional and individual engagement. We describe the characteristics that such a model should have.*

## Introduction

Laboratories are a well-accepted and an integral component of many degree programs, such as undergraduate engineering degrees. Whilst there has been surprisingly scarce research on the role of laboratories within the educational process, there is universal acceptance of their value (Feisel & Rosa, 2005). Early work by ABET (Feisel et al., 2002) analysed and categorised the various intended learning outcomes from engineering laboratories – resulting in a useful taxonomy that highlights why engineering and technology educators employ and support experimental laboratory learning.

Having accepted the educational value of laboratories, it is worthwhile to consider the challenges associated with their utilisation and support. Laboratories are usually expensive to develop and maintain. Further, the specialised nature of many laboratories means that they often have limited utility beyond specific courses, and hence have very low utilisation levels (various space utilisation surveys have indicated that it is often below 10%). Traditional engineering laboratories require students to be physically present in order to interact with equipment, limiting both student flexibility and the sharing of facilities. Taken together, these factors represent a major logistical challenge to financially challenged laboratory-based disciplines.

The recent emergence of technologies that enable physical laboratory equipment to be monitored and manipulated remotely, through the internet, has facilitated the development of online or remote laboratories (James E. Corter et al., 2007). It is important to note that these *remote* laboratories are distinct from online simulations, or *virtual* laboratories, insofar as the students are remotely interacting with real physical laboratory equipment (Bright, Lindsay, Lowe, Murray, & Liu, 2008). Research has shown that students engage with a remote laboratory quite differently from when they interact with a virtual laboratory, knowing that it is real equipment and hence the results reflect reality and not a

model of reality. See (Lindsay, Murray, Liu, Lowe, & Bright, In press) and (J. E. Corter, Nickerson, Esche, & Chassapis, 2005) for more discussion on this issue.

Most groups developing or researching remote laboratories acknowledge that this form of laboratory is not expected to replace all current laboratories, but they do represent a valid alternative for some laboratories, and a useful complement to others (Amigud, Archer, Smith, Szymanski, & Servatius, 2002). Importantly, these laboratories can be accessed by students irrespective of their physical location; they open up the possibility of substantial sharing of facilities. This concept has recently begun to attract increasing interest, with a number of sharing initiatives being either funded or proposed. Examples include the LabShare project within Australia ([www.LabShare.edu.au](http://www.LabShare.edu.au)) and the LiLa (Library of Labs) project within Europe ([www.lila-project.org](http://www.lila-project.org)). The former of these – LabShare – is a project that has been funded by the Australian Government's Department of Education, Employment and Workplace Relations, through the Diversity and Structural Adjustment (DSA) Fund. LabShare is led by the University of Technology Sydney (UTS) and is a joint initiative of the Australian Technology Network (UTS, Curtin, UniSA, RMIT and QUT). The project has funding of \$3.8 million over 3 years, including \$2.1m from the DSA fund. LabShare's mission is to create a nationally shared network of engineering remote laboratories.

For laboratory sharing to be effective various components need to converge. Firstly, laboratories that are suitable for shared remote access must be identified, developed, positioned within relevant pedagogic frameworks, and supported with relevant learning and teaching resources. Secondly, the underlying technology must support appropriate functionality related to: equipment management; user accounts; student and/or staff collaboration; experimental data handling; etc. And finally, a suitable organisational model must be developed that ensures that the laboratory sharing is handled in a way that is sustainable and maintains quality outcomes. The first two of these components are the focus of significant ongoing research. The last, however, has received little consideration but is considered to potentially to be the most challenging..

In this paper we propose a set of objectives that might underpin successful remote laboratory sharing and also outline an appropriate organisational model. In the next section we provide an overarching technical context. Following this we propose the objectives, and then outline the derived requirements and then conclude with an analysis of the implications of these requirements.

## Context

The most appropriate approach to supporting the sharing of remote laboratories across the education sector is considered to be dependent upon a number of factors including, the technical context of the laboratory sharing, the objectives of the various participants, financial issues, personal and organisational factors, and environmental constraints. The following defines these core considerations.

The basic concept underpinning the sharing of remotely accessible laboratories is that a physical item of laboratory apparatus (or, using our standard terminology, a *rig*) is configured with appropriate instrumentation that is interfaced to a computer, and to a suitable network interface (often integrated with a Web server) so that the state of the equipment can be remotely monitored by one or more students. Actuators are then added to the equipment so that the student is able to manipulate the equipment.

*Definition: Laboratory Device (Device): A single piece of equipment which forms part of a rig (e.g. a camera, an solenoid, a water tank, a PLC unit).*

*Definition: Laboratory Rig Instance (Rig): A single instance of a physical system made from various devices (including associated software and hardware) that can be used by one or more students in carrying out a distinct and discrete learning activity.*

*Definition: Laboratory Rig Type (Rig Type): The class to which a rig belongs, and within which any rig can be used interchangeably.*

Students are then able to access the equipment and carry out experimental learning activities. Whilst current remote laboratories are most often single students carrying out an activity in a single session,

other possibilities are beginning to emerge. Depending upon the capabilities of the supporting technical infrastructure, the activity may occur individually or in groups, and it may occur in a single login session or over a number of non-contiguous time sessions. In some cases a coherent set of learning outcomes may require a particular sequence of activities.

*Definition: Experiment Activity (Activity): A single instance of a distinct and discrete learning activity carried out by one or more students. Note that this may be carried out over several sessions (see below).*

*Definition: Experiment Activity Design (Activity Design): The design which specifies the intended form that a given activity should take. All activities that meet this design should have the same learning objectives and are carried out on the same rig type with a given configuration.*

*Definition: Experiment Session (Session): A single time-contiguous period during which one or more students carry out all or part of a laboratory activity.*

*Definition: Experiment Sequence (Sequence): A sequence of experiment/lab-based learning activities that together are intended to result in a coherent set of learning outcomes.*

In many cases it may be possible to change the configuration of the rig (for example, by turning off certain valves in a hydraulic system, or disabling certain components in an electrical circuit) so that the behaviour of the rig is changed. Typically a student carrying out an experiment activity, would do so using a particular combination of *rig, configuration, and activity design*.

*Definition: Laboratory Rig Configuration (Configuration): The configuration required of a rig for carrying out a particular activity design.*

A given institution (or laboratory provider) will typically have more than one rig. Indeed they are likely to have multiple rigs of a given rig type (which are referred to as a *collection*) and multiple collections of different rig types (which are referred to as a *laboratory*). It may also be possible that different institutions host the same rig types, and that these rigs, which span multiple owners, can be treated as a single logical *pool*.

*Definition: Laboratory Rig Collection (Collection): The collection of homogeneous rigs, all of the same rig type, which are co-located and managed together.*

*Definition: Physical Hardware Laboratory (Laboratory): Multiple collections of heterogeneous rigs, possibly belonging to multiple rig types, which are co-located and managed together.*

*Definition: Laboratory Rig Pool (Pool): The collection of homogeneous rigs, all of the same rig type, which may be distributed across multiple physical locations and managed by different organisations, but which can be treated as a single logical collection for access purposes.*

The resultant technical systems will need to provide appropriate coordination of access to these diverse facilities. This includes consideration of issues such as:

- Configuration of access account details for students, educators, administrators, etc.
- Establishing and maintaining information on the level of access, and the rig configurations etc. for each user; (note that an effective system is likely to need to distribute the user administration load so that it can be appropriately decentralised in order to minimise central administration effort).
- Managing access policies that control laboratory usage levels, timing etc.
- Where appropriate, tracking and reporting information on levels of access and utilisation.
- Recording information on, and making available to authorised users, information associated with individual user sessions (such as rig configurations, control, and rig outputs).

## Objectives

Whilst the specific objectives of a laboratory sharing initiative will vary, to aid the analysis in this paper, we propose the following representative statement of objectives:

- To create a 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.

Conversely, the objectives of participating institutions could include any/all of the following:

- To provide improved flexibility for students.
- To support enhanced educational outcomes for students.
- To reduce the costs associated with the development and management of teaching laboratories.

The above three points are the most often cited in the research literature in terms of justification for the development and use of remote laboratories. There has been some data demonstrating the extent to which these objectives have been met, but it has been relatively sporadic to date and there is yet to be a large-scale systematic study that demonstrates the extent of these benefits.

- To gain access to facilities that would otherwise be financially or logistically inaccessible.
- To support rapid development of new programs, and evolution of existing programs, in the face of changing student demand and evolving technologies.
- To reduce academic workloads and increase consistency through utilisation of standardised laboratories.
- To leverage a broader pool of laboratory design expertise.
- To have access to, and be seen to have access to, cutting edge facilities, for the purposes of marketing and promotion.
- To not undermine any potential competitive advantage that they may have.

Note: These latter two points relate to a degree of sensitivity to the increasingly competitive environment that exists within the education sector, but coupled with the pressure for collaboration as a way of dealing with resourcing constraints.

Similarly, individual participants (such as academics within tertiary institutions or teachers within secondary schools) may have a range of additional objectives for being involved. Apart from the above, additional objective could include:

- To gain access to facilities that allow them to support teaching approaches or educational outcomes that otherwise would not be possible.
- To make, and (importantly) be seen to be making, an intellectual contribution to teaching within their discipline.

This last point is very significant, insofar as a key professional (and often personal) motivation for many academics is the ability to make intellectual contributions within their field. Anything that is seen to undermine the ability or opportunity to make these contributions (such as provision of ‘pre-packaged laboratories’, irrespective of their quality or relevance) may be seen as a threat, and therefore be either ignored or disparaged. This may be part of the reason why the material that is made available through the Open Courseware Consortium has seen less uptake than might otherwise be expected. Conversely, laboratory facilities that allow, or even encourage, intellectual input through approaches such as customisation or critiquing, are more likely to facilitate involvement.

## Requirements

In achieving the broad project mission, the specific objectives of the institutional and individual participants need to be considered and addressed in a way that is evident to the participant. By analysing these objectives, we can identify a set of requirements that need to be met. These include:

- Be able to appropriately function within the context of the proposed laboratory sharing model (described above).
- Be financially sustainable.
- Provide financial benefits, and to be seen to provide financial benefits, to participants.
- Ensure equity between participants.
- Accommodate varying levels of contribution and involvement that change over time.
- Be flexible in the accommodation of changing needs and technologies.

- Be scalable in accommodating growth, both in terms of number of participating institutions and individuals (be it 3 or 300), and in terms of the level of laboratory equipment that is made available.
- Facilitate identification, by potential participants, of laboratory resources that may be relevant to their specific needs.
- Facilitate open sharing of information on the perceived uses, benefits, configurations, limitations and strengths of provided laboratory facilities.
- Allow participants to choose the level of information that is made public regarding their utilisation of the facilities.
- Be inclusive of diversity in the participant nature and scale – i.e. there is a big difference between large University involvement and small secondary school, or even individual involvement.
- Allow involvement from individuals (where their institution hasn't yet become involved), and to do so in a way that allows the individual to clearly demonstrate to others the value that is gained from their involvement.
- Support mechanisms for providing assurances or agreements on laboratory facility availability to participants and models for dealing with failures to meet these assurances/agreements.

As an example, it may be that an appropriate approach can be based on the use of service level agreements (SLAs) between the laboratory provider and the laboratory consumer, with suitable default penalties being specified. This is particularly complex when the facility being used is a pool of laboratory equipment drawn from multiple sources.

- Be congruent with the technologies that underpin remote laboratories – particularly the use of the Web to support remote access: this particularly means the model should be sympathetic to the use of the Web for communication and interaction.
- Accommodate a LabShare technical architecture, and the compatibility issues that arise from it.

As a way of ensuring the sustainability of the ongoing laboratory sharing, it is also important that the model will:

- Involve University administration in a way that encourages participation.
- Intellectually engage academics (possibly through provision of opportunities to make contributions to laboratory and/or experiment configuration, design and utilisation) and allow the contributions of individuals to be publicly recognised and possibly rewarded.
- Address any requirements for ongoing training that are necessary for effective engagement by the participants in laboratory sharing.

And finally there are also a number of constraints that need to be taken into account and that may influence the choice of model. In particular, the chosen approach must be consistent with:

- Copyright requirements and protection of Intellectual Property.
- Privacy legislation (e.g. privacy of student data etc.).

## Discussion and Conclusions

The above list of requirements gives a platform for supporting the effective national sharing of laboratories across institutions. The key elements will be those that establish effective engagement from both institutions and individuals. For institutional engagement, the specific cost-benefit trade-offs of using remote laboratories need to be made clear. Costs will include (potentially) the financial cost of belonging to a relevant initiative or consortia, the costs of maintaining the technical infrastructure required in managing remote access, and the risks associated with making a commitment to a resource that is managed externally. Benefits can be significant reductions in capital investment, greater flexibility in laboratory resources, and improved consistency, but importantly improved learning quality.

The issue of gaining individual engagement is potentially more complex. Academics are rarely motivated by either institutional imperatives or financial incentives (MacKeogh & Fox, 2008). A key driver is therefore the opportunity for intellectual engagement and contribution, and recognition of

these contributions by their peers. With traditional laboratories, many academics find significant personal motivation in their ability to contribute to both the pedagogic and physical design of the laboratory experiments. If existing laboratories are replaced by remotely accessed laboratories that are managed off-site with little opportunity for intellectual contribution, then there will be significant risk of lack of engagement from staff even if the laboratories themselves are highly relevant, pedagogically sound, and economically and operationally effective. This raises the question of how we can ensure that the organisational models for sharing remote laboratories can be designed to facilitate intellectual engagement with academics, and recognition of their contributions. One possible avenue worth exploring is the design of laboratory rigs that are highly configurable, so that different academics have an opportunity to *design* the way in which the remote laboratory is utilised for their students (i.e. same rig, different *activity design*). Another important aspect is to ensure that all contributions to the laboratories – both in terms of varying configurations, but also through the development of rich learning materials to accompany the laboratory – are publicly acknowledged.

Ongoing work in the LabShare project will be extending the above concepts with the aim of establishing a national laboratory sharing scheme within Australia, with the early prototype of the organisational model to be in place within 18 months. A more complete discussion of the above issues, as well as future directions, can be found in an associated white paper available for download (see under *publications* on [www.labshare.edu.au](http://www.labshare.edu.au)).

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