Remote laboratories extending access to science and engineering curricular for disabled students

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Abstract— **This paper states the general case for remote controlled teaching experiments and then goes on to discuss the implications of this approach in promoting access to science and engineering curricular for disabled students.**

Index Terms— **Accessibility, Disabled Students, Information Interfaces and Representation (HCI), User-centered design, Virtual Labs,**

I. Introduction

This paper begins with a statement of the rationale for remote experiments and then presents a review of past work of the author and highlights the some lessons for remote labs drawn from this. The author's main project in this area, PEARL, is outlined. The paper gives the reasons that commend remote labs as an extension to real labs and to the e-learning resources already offered to the students. Remote laboratories can potentially offer greater access for disabled students to the practical elements of the science and engineering curricular. The accessibility aspects of this approach are given particular attention in the paper because of this.

Finally and before concluding, the paper discusses what the author considers as promising research and development directions that will shape the future generations of remote laboratories. This centres on their integration with eAssessment approaches.

II. Rationale for Remote Experiments

Providing remote access to practical experiments may seem like a straightforward idea within distance education. It appears to offer a simple solution to problems of distance, collaboration, expensive equipment and limited availability. In this section consideration is given to whether these provide sufficient reasons for adopting the approach. Control issues and software and learning design issues mean that providing remote access is not a prospect to be entered into lightly. Analysis should be undertaken to identify where the benefits really can be practically realised. Remote access is not enough; there should be better learning provided included to otherwise to disadvantaged learners.

Practical work is universally recognized as being a key part of science and engineering education. However there are challenges to making practical work available to students in today's higher education environment. There are diverse reasons for considering the provision of practical work remotely in a given context but these all revolve around issues of students' access to the equipment and facilities they need to undertake teaching experiments.

There are three particular circumstances when the provision of experimental work remotely can enable experimental work to be more readily offered to students:

A. *When the students are studying at a distance from the institution*

B. *When the equipment required for the desired experimental work is considered prohibitively expensive (an thus sharing it between institutions desirable)*

C. *When it is difficult to cope with large student numbers given the lab-space available*

There is a big debate about when remote controlled experiments have benefits above computer simulation. The author maintains both have a place as does work with large scale distributed data sets such as weather information. It is beyond the scope of this paper to discuss this further. However the PEARL project, described later, demonstrated in a range of subject areas remote labs had a potentially valuable role in delivering the curriculum. This is particularly the case when courses are taught fully or partially online.

III. Design Considerations

Design considerations impact considerably on the pedagogic success of remote labs and their accessibility for disabled learners.

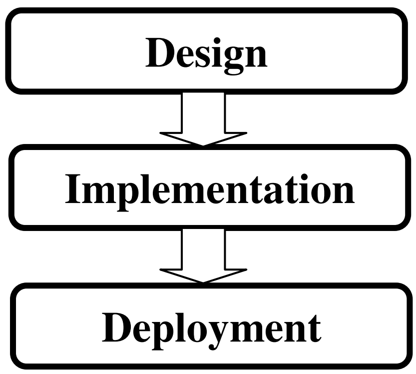

Figure 1 A simplified view of the development process

The development process shown in Figure 1 illustrates a simplified view where the design can flow through to implementation and deployment. Each of these stages instead needs to be considered as having complexities. In particular the design phase is not a single consideration but, as shown in Figure 2, it has external factors and issues that need to be taken into account. In particular the learning objectives for the student embody the consideration of the needs of the user. These are examined in more detail before briefly reviewing the other issues in the light of the experience within PEARL.

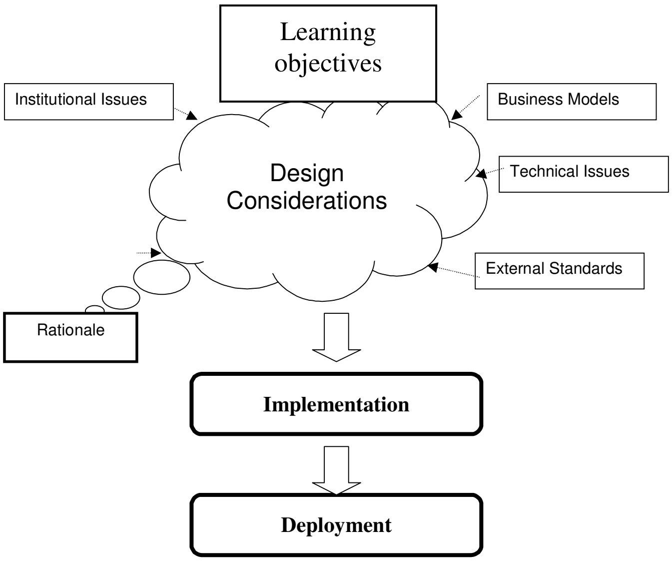

Figure 2 A route for the development of remote experiments

IV. The PEARL Project

I keep six honest serving-men
(They taught me all I knew);
Their names are What and Why
and When
And How and Where and Who.
…..
Rudyard Kipling

The author's main work in remote labs was as the project director of the EU funded PEARL project (IST-1999-12550). The project ran from 2000 to 2003 and had a total budget of € 2 million.

Figure 3 PEARL project logo

PEARL developed a modular system for implementing remote experiments. It then developed 4 diverse examples and evaluated these as separate case studies. These were:

1. a remotely controlled chemistry lab to undertake optical spectrometry of flame tests;
2. an electron microscope for use in biology labs;
3. a digital electronics design and test lab;
4. a computer visual inspection system for manufacturing engineering

The PEARL project aimed to research and develop ways to enable students to conduct real-world experiments as an extension of computer based learning (CBL) and distance learning systems. The detailed objectives from the outset were:

- to give high quality learning experiences in science/engineering education based on contemporary accounts of science learning
- to provide flexibility for studying in terms of time, location, or special needs by bringing the teaching lab to the students
- to give students access to expensive and safety critical experimental facilities
- to extend Internet course delivery to accommodate practical experimentation
- to provide Internet-based solutions that allow students to collaborate at a distance while conducting experiments
- to facilitate the learning of science as a process using CBL systems

The technological objectives were strongly related to the educational objectives and sought to identify those aspects that were critical to the successful implementation of the proposed approach. These objectives were stated:

- That the system facilitates collaborative interaction between students and, as well as remote control, observation and measurement of teaching experiments
- The remote laboratory must be based on a common control and communications channel

for all components and experimental elements within the remotely controlled laboratory, and

- Standard modules from which much of a particular installation/experiment will be constructed
- That all features of the system made available through the students' and tutors' PCs must be fully accessible using single switch control only
- The visual and audio interfaces are each fully sufficient on their own
- The system must have a fully integrated collaborative working environment.

These objectives were met across the 4 case studies. PEARL systems worked collaboratively in support of remote experiments and incorporated switch control, visual and audio interfaces. Particularly in the case of the optical spectrometer, implemented by the Open University, advanced accessibility features were demonstrated. This enabled people with physical and sensory impairments who were unable to participate in the face-to-face lab version of the experiment to do so via the remote interface.

The PEARL project was led by the Open University with the other members of the consortium being: University of Dundee, Faculty of Engineering at the University of Porto; Computer Science Dept. at Trinity College Dublin and Zenon S.A. of Athens Greece.

A key finding of the PEARL project was that its high cost approach to advanced remote labs was prohibitive in many educational settings. Since the project ended, the author's work has been on low cost remote labs based on the Lego MINDSTORM™ system. These have been developed mostly for physics and engineering experiments.

The Lego MINDSTORM™ is a programmable microcontroller embedded within a Lego brick. It has been used with the Lego Technic™ construction system to realise a range of teaching experiments including: Newtonian mechanics; principles of flight and simple robotics. The MINDSTORM™ controller is connected to a PC web server so that it can be programmed and parameterised remotely by the student. Simple web cams are used to enable the students to view the experiments.

V. ACCESS FOR DISABLED STUDENTS

Universities may wish to consider the additional potential benefit of remote experiments of providing access for students with disabilities who may not be able to access a laboratory, or who cannot operate laboratory equipment.

Universities who wish to develop remote experiments may find this a useful tool in making science and engineering courses more accessible. This may be particularly relevant in countries which have introduced legislation to reduce discrimination against people with disabilities, in particular students with disabilities. The US and UK and many European countries[1] have such legislation. Clearly, whether or not the aim of a university in adopting remote experiments is to make courses more accessible, it is important to make the remote experiment (in particular the user interface to control it) accessible to disabled students as a good design principal.

It is not the scope of this paper to discuss in detail accessible design. Other papers by the author can be consulted for this [1, 2] and there are numerous other publications giving the detail for the particular technologies used (e.g. JAVA as used in PEARL). However the role of remote labs in promoting access for disabled students of science and engineering are highlighted here.

If the interfaces to remote labs are designed according to established accessibility criteria, e.g. WCAG2.0 [3], then remote experiments can extend access to the science and engineering curricular, especially the practical elements. This indeed can make such practical elements accessible to them when they would not be if undertaken in a face-to-face lab. Well designed computer interfaces can overcome challenges due to physical or sensory disabilities. In some case full accessibility is achieved by facilitating collaborative work with another student. For example a blind student can have an observation voiced to them as they control the computer interface. This was the case in the optical spectrometer in PEARL. A student with physical disabilities unable to operate an instrument in the lab can be enabled to do so via the computer. These enabling opportunities can similarly be extended when reading or presenting data in the lab exercises.

VI. RESEARCH AND DEVELOPMENT DIRECTIONS

The author's current research interests include accessibility in eAssessment approaches. There is an obvious potential role here in the use of remote labs to assess the practical aspects of a course. However beyond that practical work can be used to assess the students understanding of underlying theory either as a formative assessment or even in summative assessment. Remote experiments offer some advantages here over the traditional teaching labs. For instance it is often possible to better integrate the practicals with the related teaching and to manage a cohort of students undertaking the same practical in a given period in parallel with this teaching.

This relationship between eAssessment and remote labs and related access issues for disabled students is subject to further research and pilots are planned by the author which are currently subject to funding proposals.

VII. CONCLUDING COMMENTS

Remote Experiments are now to be found widely in education although not as widespread as envisaged by proponents, including the author, 10 years ago. The benefits of remote experiments particularly in a distant learning context are well accepted and have been demonstrated in numerous projects and deployed courseware. Where accessibility issues have been adequately addressed in the design of the experiment and the remote interfaces practical work can effectively be made available to disabled students. It is envisaged that legislative and economic drivers will make this increasingly so over the next 10 years.

[1] See a list at http://www.w3.org/WAI/Policy/

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[3] **W3C** Web Content Accessibility Guidelines, at: http://www.w3.org/TR/WCAG/