Evaluating learning experiences in virtual laboratory training through student perceptions: a case study in Electrical and Electronic Engineering at the University of Hong Kong

Cecilia Chan and Wilton Fok

Abstract

With recent advances in information technologies, a new mode of laboratory known as the "virtual laboratory" has begun to revolutionise engineering education. This development has generated discussion about the fundamental learning outcomes of laboratory training courses and, ultimately, an interest in the consequent changes to the student's learning experiences.

This exploratory case study describes the initial phase of a research agenda that is focused on investigating the effectiveness of virtual laboratories in the Department of Electrical and Electronic Engineering (EEE) in a research-intensive university. The long-term goals of the agenda are to add to the literature of how effective virtual EEE laboratories are (in terms of delivering specific learning outcomes, and also engaging and motivating students and teachers), and to discover whether they can ultimately become a substitute for traditional laboratory training by providing an equivalent and comparable learning experience for students.

Introduction

Critical elements of engineering are problem solving, designing, creating and building. Thus, to adequately prepare students for a career in engineering, theoretical knowledge and practical experiences are a must for their education. Theoretical learning is prevalently delivered through lectures and tutorials, while practical experiences are often delivered through hands-on laboratory sessions. Laboratory training is absolutely vital in engineering and in most science-related disciplines. It helps students to understand and reinforce their theoretical concepts, and also targets a range of learning outcomes, including experiential learning processes that cannot be delivered through lectures and tutorials. Laboratory training has been a mandatory curriculum requirement for academic accreditation by many professional engineering bodies such as the Engineering Council of the United Kingdom (2004) and the Hong Kong Institution of Engineers (2003). While there seems to be a general consensus that laboratories are indeed necessary, most studies on engineering education seem to focus on curriculum design and innovative in-class or laboratory learning activities and technologies (Noguez and Sucar, 2006; Xiaoyan et al., 2005). Laboratory curriculum design and its learning outcomes tend to be excluded from educators' interests (Feisel and Rosa, 2005).

With recent advances in information technologies, a new mode of laboratory known as the "virtual laboratory" has begun to revolutionise engineering education. This development has generated discussion about the fundamental learning outcomes of laboratory training courses and, ultimately, an interest in the consequent changes to the student's learning experiences.

This exploratory case study describes the initial phase of a research agenda that is focused on investigating the effectiveness of virtual laboratories in the Department of Electrical and Electronic Engineering (EEE) in a research-intensive university. The long-term goals of the agenda are to add to the literature of how effective virtual EEE laboratories are (in terms of delivering specific learning outcomes, and also engaging and motivating students and teachers), and to discover whether they can ultimately become a substitute for traditional laboratory training by providing an equivalent and comparable learning experience for students.

The basis of this exploratory phase was to investigate student perceptions of their experiences during an intensive one-month compulsory summer EEE laboratory training session. In an effort to elicit an accurate depiction of the perceptions of the virtual laboratories, it was important that students compared their experiences with both traditional and virtual labs (Stuckey-Mickell and Stuckey-Danner, 2007). This summer laboratory session contained both traditional hands-on and virtual laboratory experiences in order to facilitate this.

Though the ultimate goal of the authors is to examine the effectiveness of virtual labs as an instructional tool, the initial purpose here is to glean student perceptions of the tool from an evaluative perspective. It is hoped that findings from this study will provide useful information for instructional improvement as well as adding to the literature in this area.

Literature review

A virtual laboratory can be defined as an environment in which experiments are conducted or controlled partly or wholly through computer operation, simulation, and/or animation either locally or remotely via the internet. With regard to the computer animation type of virtual laboratory, the experiment is often a graphical model of the actual experiment. This type of virtual laboratory does not include physical hardware, but it allows the user to observe the process and the end product by way of animation. It often allows users to direct the process and the end product with some controllable variables of the experiment in the software. Hashemi et al. (2005) developed a virtual materials science laboratory on metallography for tensile testing. The software is fully interactive and its development was based on Macromedia technologies. It also has the ability to provide quizzes and immediate feedback to the users. Similarly, Lee et al. (2002) developed a virtual training workshop for ultra-precision machining and inspection facilities. This mimics the real operation of the process, which is something that might not be economically viable in a conventional training workshop. The computer simulation type of virtual laboratory usually contains some physical instruments and hardware, and the simulation may be on the data acquisition part and/or the components. Kocijancic and Sullivan (2002) described two sets of scientific experiments: one for wave phenomenon and the other for biomass growth by integrating a data acquisition system and physical components (such as plants and soil) into the virtual laboratory. The computer operation type of virtual laboratory is often a real laboratory with components in a confined space that the user can access remotely through a computer, for example at Carnegie Mellon University (CMU) (1998), students can conduct real experiments in the EEE virtual laboratory remotely using personal computers. The CMU system also includes a live video stream so that students can observe the experiment as if they were physically there. This has the advantage of allowing access to a laboratory that may otherwise be restricted due to safety, time and distance, and the technology greatly enhances the flexibility of laboratory education.

In this case study, a system which allows students to conduct simulated laboratory experiments with the use of laptops has been researched and developed. This included designing peripheral hardware and circuits for interfacing with the experiment simulators and virtual instrumentation tools in the system (such as a function generator, a digital multimeter and a digital oscilloscope). Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) has been deployed in the University's EEE laboratory. It provides a virtual environment for students to operate a series of graphical units, each represents an instrument or experimental object. Students can conduct remote virtual experiments at any time by a local machine or by a remote machine via the internet. The system has been set up for students on the *Laboratory Training* module, as a part of the Electrical and Electronic Engineering course. Figure 1 shows the system.

Methodology

A survey questionnaire with both closed and open-ended questions was designed and data was collected in order to investigate student perceptions of their experiences of virtual and traditional laboratories in this case study. It consisted of basic demographic questions (such as gender and ethnicity), five questions for evaluating student perception of traditional and virtual laboratories, and three other general questions on the usage of the laboratories using a 5-point Likert scale (where scores of 1-5 were used to indicate levels of agreement with the statements).

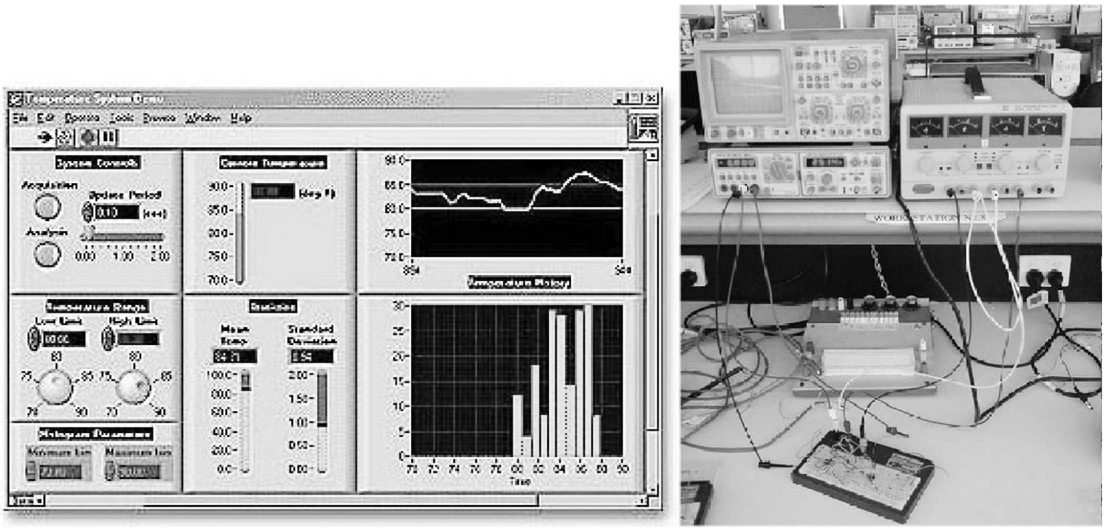

Figure 1. The LABVIEW virtual laboratory at the University of Hong Kong

Second year students in the compulsory summer laboratory training course (studying a three-year honours degree in Computer Science, Industrial and Electrical Engineering programmes) were asked to fill in the survey. The laboratory training course comprised of both traditional and virtual laboratory sessions (about three quarters of the course was traditional and one quarter was virtual). It was a very intensive training course running from 9am to 5pm everyday for one month. The laboratory experiments included electrical and electronic measurements such as control and input/output elements with signal generator, oscilloscope and multimeters. Some design projects were also included. Students who joined the course already had previous traditional laboratory training in EEE during their first year of the programme. However, these training courses were their first experience of virtual laboratory training.

Results

A total of 50 engineering students (13 females and 37 males) participated in the survey. Forty-six of them were local students, one was international, two were from mainland China, and one did not answer that particular question. The data from the Likert-type questions indicated that the virtual laboratories were generally well-received. However, responses indicated that students perceived traditional labs as being more “easy to operate”, “easy to understand”, “flexible to use in relation to time and place” and “satisfying” than virtual labs overall. Table 1 shows the percentages of students who indicated strong agreement or disagreement on each Likert-type item.

There was a general consensus that virtual laboratories are more suited to senior students than first years. From the survey data, 48% of the respondents strongly agreed or agreed with that statement in contrast to 4% who strongly disagreed or disagreed, although there were also 48% who neither agreed nor disagreed with the statement. 81% of the students considered using the virtual laboratory outside laboratory hours through the internet.

A question about the ratio of laboratory hours between traditional practical laboratories versus virtual laboratories was also asked in the survey. Forty seven responses were collected, and out of these only two students did not want to spend any time in virtual laboratories. One of the students commented that *‘I don’t know what is going on in the virtual workshop training at all.’* There was also one student who did not want to participate in traditional laboratories, as he was a computer science student who believed that he did not need traditional EEE laboratory training for his career. He commented that *‘For a computer scientist, traditional laboratory workshop is not suitable and required.’* In general, students had a slight preference for longer traditional laboratory hours over the virtual laboratory. In addition, some students have provided their opinions on the two types of laboratories (given in the comment box in the survey). They commented that:

> *‘I think that both virtual and practical labs are important, it is useless to be a star in either part but not the other.’*

> *‘Virtual lab workshop is better for familiarisation of theories, but practical*

Table 1. Percentages of students who indicated strong agreement - disagreement in the survey

Survey Items		%				
I found the traditional laboratory workshop:	**Sample (n)**	**SA**	**A**	**N**	**D**	**SD**
Easy to operate	47	8.5	49	34	8.5	0
Easy to understand	50	8	48	36	8	0
Flexible to use in relation to time and place	50	6	46	34	8	6
Stimulating	50	12	38	42	6	2
Satisfying	50	12	40	40	8	0
I found the virtual laboratory workshop:	**Sample (n)**	**SA**	**A**	**N**	**D**	**SD**
Easy to operate	49	12	45	37	4	2
Easy to understand	50	10	42	38	6	4
Flexible to use in relation to time and place	50	10	40	40	8	2
Stimulating	50	8	44	38	6	4
Satisfying	50	6	42	42	6	4

Survey Items	Sample (n)	Strongly agreed/Agreed %	Neutral %	Strongly disagreed/ Disagreed %
I think Virtual Lab Workshop is more suitable for senior students (2nd year students and above)	50	48	48	4
I think that I learn and understand more in a virtual lab environment than a traditional lab	50	40	46	14

Survey Items	Sample (n)	Will	Will not
If I can use virtual laboratory workshop over the Internet instead of physically staying in a laboratory, I (will/will not use)* the virtual laboratory workshop outside lab hours for distance learning.	42	81	19

lab is also necessary as practical skills are also needed.'

'Practical lab should be kept, because we can learn the basic principle from it.'

This showed that the student's perception is that the substitution of traditional laboratories with virtual laboratories may not yet be a complete solution but that virtual laboratories can be used in addition to the traditional methods to facilitate enhanced study outside laboratory hours.

Another student also highlighted one of the disadvantages of virtual laboratories: *'Virtual lab learning may encourage reduction in team work and communication between tutors/ students.'* This is an area that educators are most concerned with, since transferable skills have been high on employers' agendas as necessary graduate attributes in recent years (Atlay and Harris, 2000; Council of the European Union, 2001; University Grants Committee Hong Kong, 2007). In a later phase of this research study, we hope to gather more ideas and opinions in order to better assess and develop our students' transferable skills through virtual laboratories (by including technologies such as forums and live feedback). Table 2 shows projected pedagogical advantages and disadvantages of virtual laboratories.

Discussions and conclusions

The purpose of this exploratory case study was to investigate student perceptions of their experiences during an intensive one-month compulsory summer EEE laboratory. One limitation of the study was the small sample size. There is a need to continue this line of research with a larger sample and also with

Table 2. Projected pedagogical advantages and disadvantages of virtual laboratories

Advantages of virtual laboratories	Disadvantages of virtual laboratories
Enables laboratory experience at any time and anywhere	Discourages students from learning the physical instruments and real devices
Allows students more opportunities to practice experiments, particularly for those that may not be easily replicated due to resources, time and safety issues	Remote access discourages direct collaboration and interaction amongst students and teachers
Provides a safe workshop environment without the need for supervision	Increased risk of plagiarism in assessment
Enhances students' enthusiasm for learning through interactivity	Physical, practical skills that are expected of an engineer are not honed
Increase students' IT literacy	
Many industries are using simulation software for testing and development and students are getting a flavour of this	
Contact laboratory hours are scarce. Students can use virtual laboratories to reinforce the theoretical concepts they learn in class	
More cost-effective, particularly for complicated circuits that may require a number of trials and errors	
Can provide attendance and other student information	
Online feedback and assessment can be made readily available	

different stages. We anticipate surveying a larger sample in future years and also running focus group interviews to gather in-depth opinions from students. Individual interviews with teachers will also be arranged to gather their perceptions and ideas on practices and assessments.

The virtual laboratory is an emerging trend for engineering education. Students can conduct experiments via a computer in a time-efficient and cost-effective way. There are many advantages of this new environment for laboratory training such as maximising time and space flexibilities, enhancing students' enthusiasm for learning through interactivity, improving time efficiency, simplifying complex procedures so that more complicated workshops can be conducted, offering a safe workshop environment, and enabling a convenient platform for student assessments. However, virtual workshops can also discourage students from becoming familiar with physical instruments and real devices. In relation to the transferable skills such as team-work and communication skills which can often be found and delivered in traditional laboratory training, the remote access features in virtual laboratory training could discourage direct collaboration and interaction. Further work is required in the curriculum design of virtual laboratory training to incorporate collaborative assignments and discussions that may enhance students' transferable skills.

The requirements of laboratory training for engineering students are always evolving and, as with the introduction of many other new technologies, the benefits are often accompanied by shortcomings. However, on the whole, the virtual laboratory can address some challenging demands on engineering education made by the modern industry, economy and society.

The current work represents the commencement of a promising research programme, but future development of the virtual laboratory as an instructional tool and the delivery of its learning outcomes will need to be carried out. Virtual and online learning in the area of engineering laboratories are still new in so many ways; more research is needed if educators are to be able to fully exploit this delivery medium and its related tools in the enhancement of teaching and student learning. ■

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Contact details

Dr. Cecilia Chan Assistant Professor, Centre for the Enhancement of Teaching and Learning, University of Hong Kong.
Email: cecilia.chan@caut.hku.hk

Dr. Wilton Fok Senior Teaching Consultant/Industrial Training Manager, Department of Electrical and Electronic Engineering, University of Hong Kong.
Email: wtfok@eee.hku.hk