

Integrated laboratory experiment setup to empower the engineering education in distance mode

ILES to empower the engineering education

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W.A. Rasika Nandana and W.R. de Mel

Department of Mechanical Engineering, The Open University of Sri Lanka, Colombo, Sri Lanka

Abstract

Purpose – The purpose of this paper is to introduce an integrated laboratory experiment setup (ILES) to overcome problems encountered in open distance learning (ODL) especially when offering engineering degree programmes.

Design/methodology/approach – Engineering laboratory experiments can be classified as experiments which are performed with the intention to inculcate theory, and second, to provide hands-on experience. The ILES integrates both types of experiments with face-to-face laboratory (FFL), online remote laboratory (ORL), and multimedia demonstrations, and it helps to reduce traditional FFL duration by 50 per cent. The first phase of the ILES provides an opportunity to refer multimedia demonstrations of the experiments. Thereafter, students attend the first FFL session, which covers about 25 per cent of the experiments. In the next step, 50 per cent of the experiments are offered using the ORL, via the internet while interacting with real equipment and making actual observations. The final step is used to accomplish the rest of the experiments (25 per cent) in FFL which facilitates the clarification of any problem that may occur in the ORL.

Findings – This blended laboratory system will help to achieve ODL objectives while utilising resources productively and cost effectively. Having implemented the idea and based on the information received from the stakeholders, this has proved to be a workable solution to one of the difficulties faced by ODL students.

Research limitations/implications – The level of outcome of the students has to be observed and analysed in comparison with the traditional laboratory setup.

Practical implications – Some experiments (e.g. thermodynamics) which need more safety precautions are difficult to offer via ORL.

Originality/value – The ILES is a blended setup including FFL, ORL and multimedia demonstrations and it is a novel concept which is most applicable to engineering/science programmes offered in ODL mode.

Keywords Integrated laboratory experiment setup, Online remote laboratory, Open distance learning

Paper type Research paper

Introduction

Distance learning education has its origins in the eighteenth century. In 1728, a teacher named Caleb Philipps offered shorthand courses as weekly mailed lessons (Holmberg *et al.*, 2005) and in 1840, Sir Isaac Pitman delivered shorthand courses by mail



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(Kolesinski *et al.*, 2014). The University of London, established in 1858, is the first university in the world to offer distance learning degrees through its external system (Tait, 2003). The United Kingdom's Open University established in 1969, is the first open university in the world (Matthews, 1999). The Open University of Sri Lanka (OUSL) was established in 1980 with the same legal and academic status as other national universities in Sri Lanka.

Distance education is a mode of teaching and learning, characterised by separation of teacher and learner in time and/or place for a greater part of the educational transaction. This is mediated by technology for delivering learning content with the possibility of face-to-face interaction for learner-teacher and learner-learner interaction, provision of two-way didactic communication, and acceptance of industrial process for division of labour, and economies of scale (The Commonwealth of Learning, 2015).

Open and distance learning (ODL) refers to the "provision of flexible educational opportunities in terms of access and multiple modes of knowledge acquisition". Flexible means the availability of choices for educational endeavours anywhere, anytime, and anyhow. Access means opportunity made available to all, freeing them from constraints of time and place. Multiple modes mean the use of various delivery systems and learning resources (The Malaysian Qualifications Agency, 2011). Additionally, ODL fulfils the fundamental right to learn and helps human capital development of a country and the world.

Apart from open universities, distance education was practised by many other conventional universities of the world and at present, distance education in combination with conventional education is used as a dual mode education to fulfil the learner requirements. The Faculty of Engineering Technology of OUSL is one of the pioneering faculties to offer hard engineering programmes through distance mode in the world (Liyanagama, 2014).

Laboratory class is a main and essential component of engineering education. The three basic types of engineering laboratories are development, research, and educational. Practicing engineers attend development laboratories while research laboratories are used to seek broader knowledge that can be generalised and systematised. Alternatively, diploma and undergraduate students attend instructional laboratory to acquire knowledge, already possessed by practicing engineers (Feisel and Rosa, 2005).

Problem

According to ODL definition, the idea of OUSL was not merely to cater to adult education, but a concept that embodies the belief that learning is a constant process and all individuals have a right to learning opportunities (Reggie, 2015). Still, problems exist when providing lifelong education for all.

One primary aim of the OUSL is to provide educational opportunities to employed people. In 2014, over 60 per cent of students were not employed when they enrolled in the engineering degree programme. The total number of students who dropped out from the OUSL engineering degree programme during 2012/2013 academic year was 1,258. Among dropouts, 50 per cent were employed and one major reason for the employed students to record a high dropout rate is their workplace commitments.

Another reason was the lack of facilities, especially laboratory facilities, particularly for outstation students, whose dropout rates were 20 per cent higher than of those who lived in the vicinity of Colombo, where the central campus is located

(Liyanagama, 2014). Ismail (1997) also mentioned that variables related to distance from home to the institution were influential on students dropout from the OUSL.

According to Vidanapathirana (2010), approximately 53 per cent of the OUSL's admissions are restricted to Western Province, which shares only one-third of country's population. If one removes the "language", "management", and "education" programmes, this will escalate up to 75 per cent.

Fozdar *et al.* (2006) found that the costs associated with attending laboratory courses was the second highest personal reason (38.24 per cent) for withdrawal from the Bachelor of Science programme of Indira Gandhi National Open University in India. Their study identified nine main reasons for dropping out of students, among which, 52.94 per cent mentioned that distance was their main difficulty in attending laboratory sessions. It indicates other ODL universities also face similar problems as OUSL.

According to OUSL statistics, student enrolment of the Western Province in 2013/2014 academic year is 49.9 per cent of the total students, as presented in Figures 1 and 2, while population of the Western Province represent 28.7 per cent of the country population. Further, 46.3 per cent of the total students are registered in the Colombo centre (Central Campus) as illustrated in Figure 3, although OUSL operates 26 regional and study centres around the country as shown in Figure 4 (Public Information Division of the OUSL, 2013).

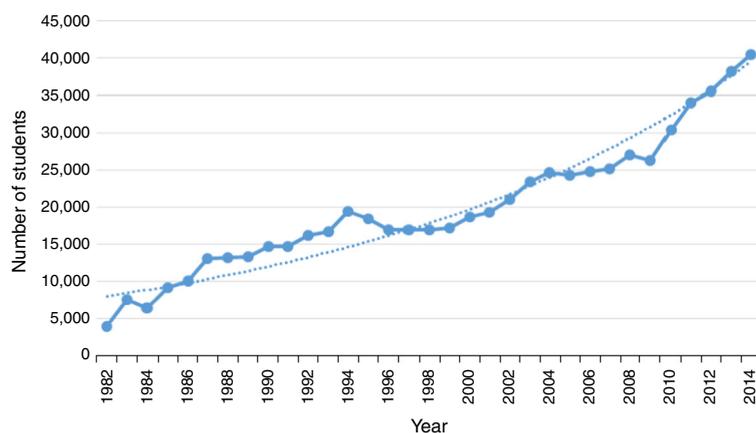


Figure 1.
Student enrolment
of the OUSL

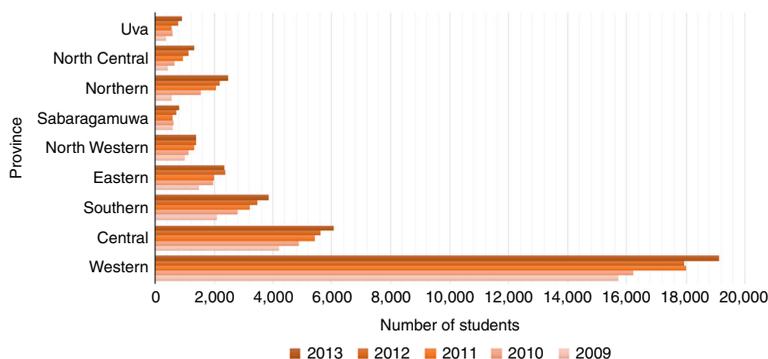


Figure 2.
Student enrolment
of the OUSL
by province

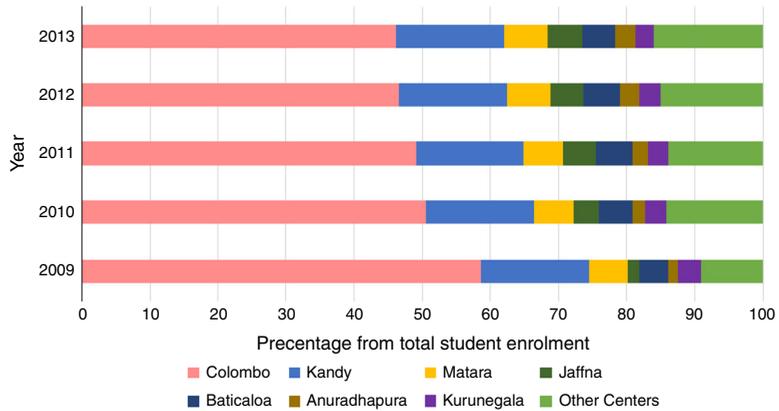


Figure 3.
Student enrolment
in key centres

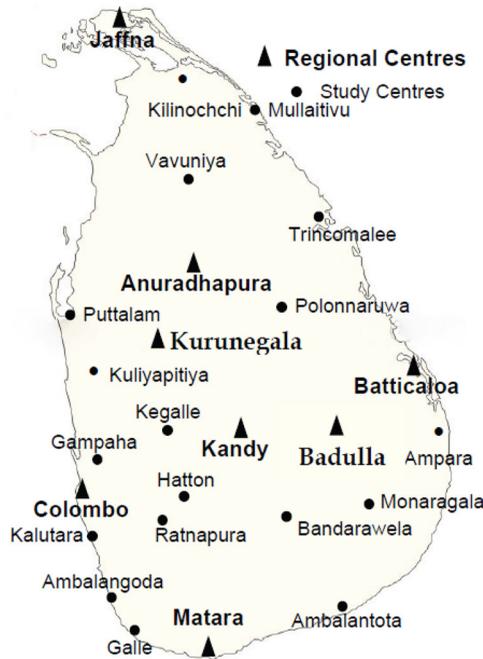


Figure 4.
Regional and study
centres of the OUSL

Major educational methods/components used by the OUSL to deliver engineering education in ODL mode are printed course materials, the online learning management system – Moodle, virtual classes, tutor marked assignments, continuous assessment tests, day schools, and final examinations. Continuous assessment tests and final examinations are held at regional and selected study centres around the country. Generally, day schools (face-to-face class) are conducted at the Central Campus in Colombo and if a certain number of students have registered for a particular subject in a regional centre, the day school will also be held at that centre. However, most laboratory experiments are available only at the Central Campus in Colombo due to lack of resources in many regional centres. As illustrated in Figure 1, number of

students of the OUSL increases annually in an exponential growth and the university faces difficulties with expanding resources.

Aluwihare *et al.* (2015) found that, the lack of laboratory facilities at the regional/study centre network is a major institutional cause for the prolonged time taken to complete the bachelor's degree programmes offered by the Faculty of Engineering Technology, the OUSL. They highlighted the fact that learners from other regions have to travel to Colombo and find accommodation in order to participate in the laboratory classes, and thus many employed students give-up the laboratory component of the courses (which is compulsory) as they cannot spend the time needed for the above venture. According to them, the travelling time and cost of commuting to the main centre located in Colombo has contributed hugely to the prolonged duration for the completion of the degree programme.

According to Hill (2009), work-related challenges are the most prominent difficulty among various hardships identified by OUSL learners. Similarly, Hill indicated that "Learners who work may have difficulties to complete course work, and may be unable to attend practical and examinations".

Methodology

ODL institutes face new challenges while delivering laboratory classes in engineering and science programmes. An online remote laboratory (ORL) system was developed in the OUSL as a solution (Nandana *et al.*, 2012, 2014, 2015). It allows students to conduct practical exercises with real equipment, without being physically present in a conventional laboratory. Remote laboratories provide opportunities to students to perform more practice/additional experiments to help reinforce concepts and provide further understanding (Lindsay *et al.*, 2007). However, it is not possible to replace all practical sessions by remote laboratories due to the need of hands-on experience, and the difficulty of implementing certain experiments using remote laboratories.

If traditional face-to-face laboratory (FFL) is totally replaced by ORL, there is no opportunity to work with real laboratory equipment. In addition, it is difficult to clarify problems encountered while performing the remote laboratory. Therefore, an integrated laboratory experiments setup (ILES) is proposed by integrating FFL and ORL with additionally introducing video demonstrations of the experiments. Workflow of the system is illustrated in Figure 5.

As presented in Figure 5, this laboratory setup is broadly divided into four phases. However, when needed, the number of stages can be increased by splitting it into more phases.

First phase of the laboratory work is a video demonstration of the relevant experiment/s and, it will provide necessary theoretical background of the experiment while demonstrating required steps of the experiment. However, to ensure that students learn the process accurately by themselves, some steps in results and calculations will be purposely omitted (with notifications if necessary) in demonstrations. Learners have access to video demonstrations throughout the study programme from the beginning and the demonstration package will be distributed over the internet and/or as a CD-ROM.

After following video demonstrations, a student will be able to perform laboratory practical work. The single laboratory session currently available is divided into three sessions as FFL-stage I, ORL, and FFL-stage II.

The FFL-stage I is the second phase of the ILES. It offers around 25 per cent of the experiment to students. At this stage, the students gain necessary basic knowledge and hand-on experience by familiarising with the instrument.

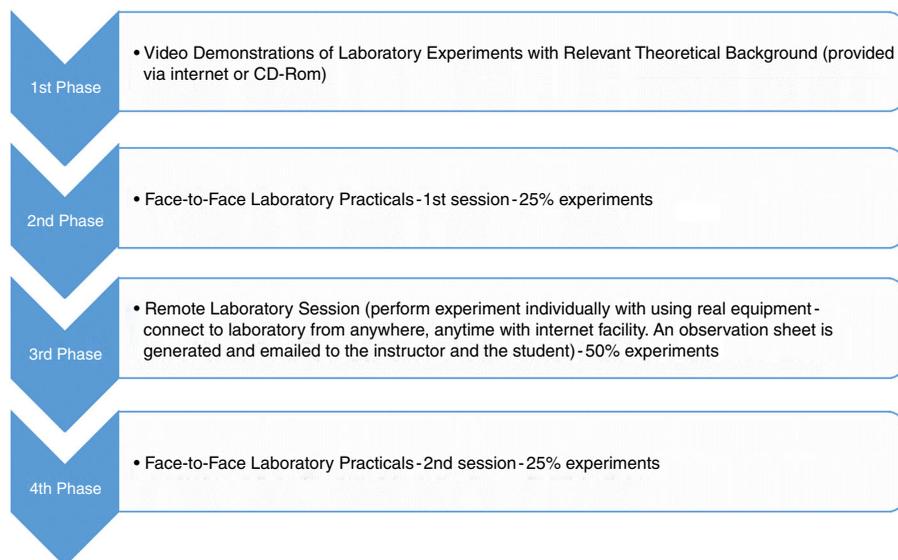


Figure 5.
Workflow of the
integrated laboratory
experiment setup

The ORL session is introduced as the third phase of the ILES, which will cover around 50 per cent of the experiments. Students have access to pre-configured laboratory setup (real equipment and components) available in the university laboratory, via the ORL system. The ORL system architecture is shown in the Figure 6. A user interface of the ORL client application is presented in Figure 7.

Again, the fourth phase provides a FFL session and it is the FFL-stage II. If a student faces any difficulty when performing experiments remotely during the ORL session, and is unable to rectify it, there is an opportunity to resolve it. Additionally, rest of the experiments can be completed in this session. This system provides progressive knowledge to students and thereby enhances the current teaching-learning process of the laboratory experiment.

In the traditional laboratory delivery, there is always an occasion to attend FFL before covering theoretical concepts of the subject. It is an unavoidable problem faced by almost all universities, considering the time/space, and resources management. Then, knowledge transmission to all students will not happen properly. Introducing video demonstration in this system will help to partially overcome this problem with

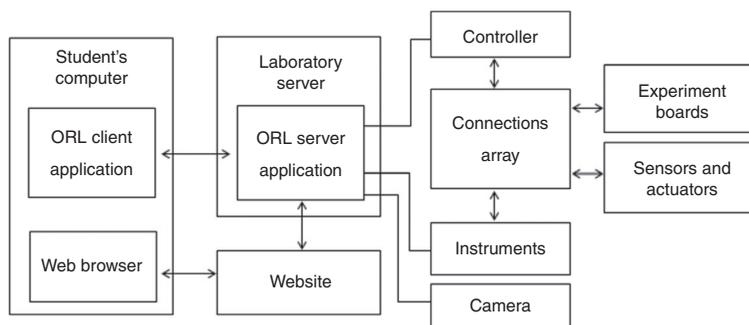


Figure 6.
The ORL system
architecture

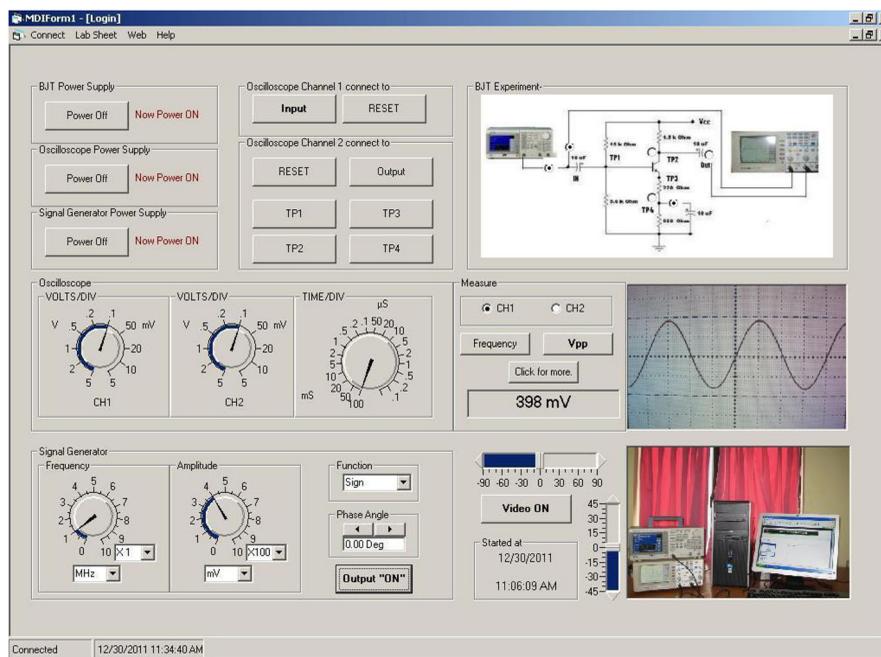


Figure 7.
User interface
of the ORL
client application

relevant theoretical background, before the FFL sessions. In addition, there is an opportunity to attend a FFL session (stage II) again, in the latter part of the semester/academic year, after completion of a considerable portion of theory.

The ORL session offers experiments specially related to understanding theoretical concepts, not to gain hands-on experiences. Therefore, proper selection of experiments for ORL and FFL is necessary. However, students have an opportunity to resolve any problems that had occurred in the ORL session at the FFL-stage II, by physically interacting with real equipment.

The survey

A survey was conducted focusing on the requirement of such a system for students to overcome problems currently associated with ODL laboratory classes of the OUSL, and collecting their viewpoints regarding ILES.

An online survey tool developed using a Google form which was administered among 270 undergraduates of the Department of Mechanical Engineering, OUSL. This sample was selected from the students who had already completed laboratory class, at least in one subject, in mechanical and mechatronics fields. Survey findings are based on 168 filled-in responses received.

Results and discussion

Replace current FFL system by ILES

According to the survey responses, 62.5 per cent students were happy to replace current system by the new system, while 21.4 per cent students have no idea regarding this matter, hence were not aware about the ILES. Only 16 per cent students indicated their dissatisfaction at replacing the current FFL system with the ILES. However, all those

16 per cent of students were unemployed and their hometown located within 20 km to the Central Campus. Thus, it is evident that distance from home to central campus is a major factor, when including face-to-face components in a distance education system.

View of employed students

A majority of employed students (95.9 per cent) like to work with ILES system than traditional FFL except three students who indicated that they could make a decision after some experience with this proposed system.

Five students commented that, if laboratory sessions were held on weekends, it might be helpful for employed students and will overcome problems they encountered. Adopting it at OUSL setup is problematic due to the lack of adequate time slots and human resources available during weekends, to include all laboratory sessions. This is due to the fact that other face-to-face sessions, such as day schools and examinations are already conducted during weekends.

According to the responses, all employed students (74 in number) face difficulties when obtaining consecutive leave to attend laboratory sessions (difficulty level: less = 12.16 per cent, moderate = 66.22 per cent, high = 21.62 per cent).

Split the single laboratory session

Splitting single laboratory session into two or more sessions was favoured by 67.86 per cent students. A student commented that:

It is better if consecutive lab sessions are limited to maximum of two days. If more days are needed, sessions should be conducted after one month, so the number of leave obtained in a certain single month is reduced.

Similar idea was proposed by 32 per cent of the students. The present ILES system itself supports this requirement.

Other problems overcome by ILES

One objective of FFL is to give opportunities for hands-on experience. However, 14 students remarked that "Most of the time, the practical was not actually performed by themselves", and the reason being, "Number of students in a group is high". Some indicated that "Time allocation for the practical is not sufficient". The ILES provide facilities to perform experiments individually and thus this problem could be partially solved.

Infrastructure facilities for ILES

Almost all students remarked that they have access to a personal computer and internet in different ways. Students (7.14 per cent), who do not have access to computer and/or internet facility at home were able to access the ORL through national online distance education service access centres (NACs), regional/study centres, or internet cafés. Regional/study centres of the OUSL and NACs are presented in Figures 4 and 8, respectively. Therefore, sufficient infrastructure facilities are available for students to access the ORL of ILES.

ORL system accuracy and enhancements

According to the statistical analysis (Nandana *et al.*, 2015) there is no significant difference between the FFL and ORL experiment results within 95 per cent confidence level. Therefore, the observations of ORL have been acceptable as the FFL observations.



Figure 8.
National online
distance education
service access
centres

The ORL collect experiment data using standard laboratory equipment (e.g. digital oscilloscope) and frequently calibration is not required. However, a laboratory technician is able to calibrate the equipment once a week to ensure the proper operation. The ORL also facilitates to perform basic calibration remotely.

According to the calculations and experimental values (Nandana *et al.*, 2015), selected network connections are within acceptable range and if server network connection is replaced with a high bandwidth connection, the transmission performances of the ORL system can be enhanced. Currently, the ORL is not available as a mobile application and in future there are plans to develop it as an open source mobile application to reach students who use smart phones frequently. Ketheeswaran and Mukunthan (2016) also suggest that, it is necessary to take immediate action to promote the use of smart phones in learning environments in the OUSL.

Conclusion

According to the survey results, it is evident that, employment and distance from their residences to central campus are the major challenges faced by students with the inclusion of face-to-face components in a distance education system. The IELS helps to overcome such challenges, when delivering laboratory classes.

Since the number of students of the OUSL is exponentially growing annually and resources are limited, this laboratory delivering model is a good solution to manage limited laboratory resources effectively and efficiently.

Almost all employed students face difficulties to obtain consecutive leave to attend laboratory sessions. The IELS solve this problem by reducing FFL sessions up to 50 per cent and dividing single FFL session into two or more sessions.

The video demonstrations (first phase of IELS) is helpful to properly understand laboratory experiments and the ORL (third phase of IELS) provide facilities to perform

experiments individually and remotely. It also permits to repeat the experiment if they need more experience.

Therefore, ILES enhances the effectiveness of the learning process of laboratory classes while achieving ODL objectives.

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Corresponding author

W.A. Rasika Nandana can be contacted at: wanan@ou.ac.lk