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TriLab – a combined remote, virtual and hands-on laboratory as a novel reusable learning object (RLO) for Supporting Engineering Laboratory Education

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Introduction

Reusable Learning Object (RLO) is, in brief, a conceptual model of a shared vessel of teaching and learning content which is normally developed using IT tools. Attention have been paid recently towards using RLOs in educational processes for facilitating better learning and minimizing costs associated with improving teaching and learning. The importance of a laboratory experience in engineering education curricula has been emphasized in a large number of science and engineering education articles (Johnstone et al 2001; Hofestein et al 2004; Feisel et al 2002; Kirschener et al 1988; Ma et al 2006). Wankat observes that only 6% of the articles published in the Journal of Engineering Education from 1993-2002 had 'Laboratory' as a keyword (Wankat 2004). In response to the recent recommendations in the literature regarding the engineering laboratory education, we worked on developing an Online Laboratory Learning Object (OLLO) for enhancing the students laboratory experience, the OLLO was developed for the process control laboratory taught through various courses at the chemical engineering department of Loughborough University.

The Process Control Lab

The process control lab is a coherent part of the second year Instrumentation, Control and Industrial Practice module at the Chemical Engineering Department at Loughborough University. The experimental rig of the hands-on process control lab was designed to mimic a real surge tank system which is a typical chemical engineering process. The laboratory is a compulsory part of the module designed for undergraduate engineering master (MEng), bachelor (BEng), and bachelor in science (BSc) programmes in chemical engineering at Loughborough University. The lab aimed to introduce students to the principles of control engineering, such as the main components and instruments of a feedback loop, the concept of open-loop control, feedback control, proportional-integral-derivative (PID) control, and PID tuning. The hands-on laboratory consists of two 3 hours sessions, scheduled for two consequent weeks. In the first week the students were introduced to the elements of typical feedback loops such as sensors, actuators, controller, and process. The main objectives were of the first session are: calibration and hysteresis of the level sensor; Calibration, hysteresis, installed characteristics and relative resistance of the control valve. During the second week, students were introduced to control engineering concepts. The aim of the experiments in the second week is to help students appreciating the advantages of automatic control compared to manual operation, and to equip the students with qualitative evaluations of the differences among proportional (P), proportional-integral (PI), and proportional-integral-derivative (PID) controllers. In general, all students were asked to prepare for the lab by reading the lab manual before the session and by downloading the virtual laboratory software.

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TriLab and the Online Laboratory Learning Object (OLLO)

There has been recent shift in engineering education towards embracing constructivist pedagogy and experiential learning practices. There is more demand on supplementing the theoretical lectures in the engineering courses with authentic real applications, i.e. laboratory demonstrations. Most of the previous obstacles can be overcome by developing a self contained entity that includes instructions and information about the experimental rig, the hardware operation, the experiment purpose, brief background theory, simulation of the rig, and experimental procedure for the sake of learner-centered approach of conducting the experiment, and furthermore a remote operation capability of the hands-on lab for the sake of sharing the whole entity and the lab rig among different institutions which could result in dramatic drop of setting up new labs and will considerably enrich the engineering pedagogy by embedding new laboratory resources that would have been possible to access. We call such entity the "Online Laboratory Learning Object", or in brief OLLO. In definition, the Online Laboratory Learning Object (OLLO) is a learning object that is particularly designed for the laboratory pedagogy and is characterized by the following:

1- *It is a learning object which includes self contained learning content related to the hands-on laboratory experiment that enables learner-centered approach of learning the experiment.*
2- *It is incorporating remote operation of the physical hands-on lab rig, mainly through the internet.*
3- *It is designed to mimic a relevant hands-on laboratory when operated offline by using virtual instrumentations.*
4- *It is preferred that OLLO would include video transmission of the hands-on test rig.*

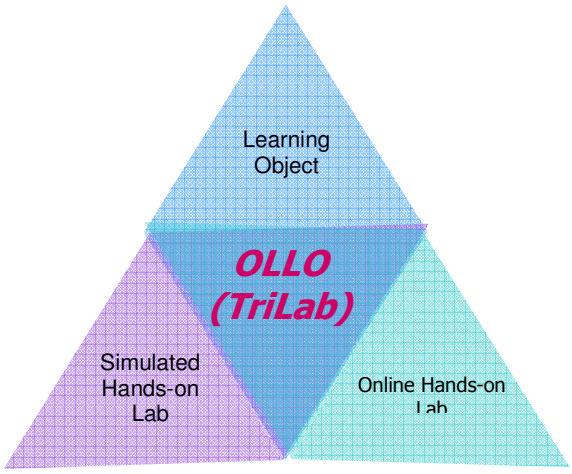


Figure 2. Conceptual model of the TriLab as an OLLO.

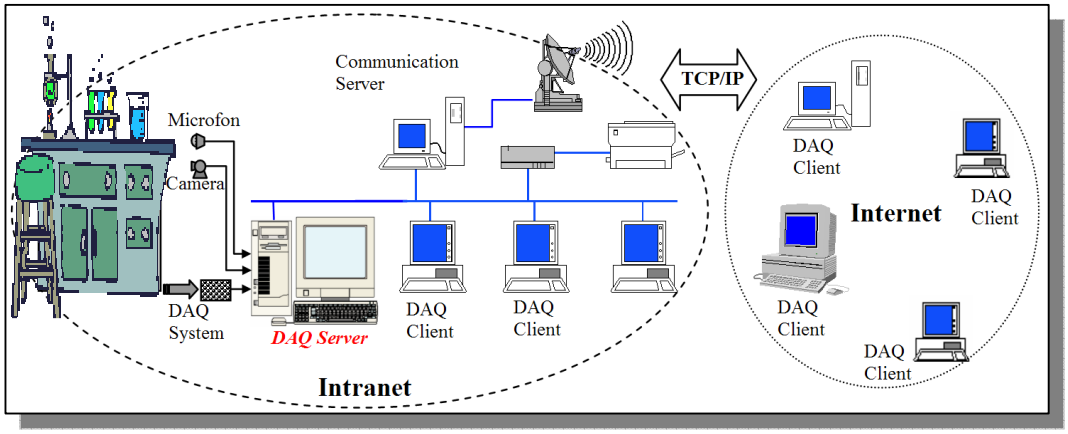


Figure 3. Core Communication Architecture of the OLLO.

The OLLO without remote operation of the physical instruments is a learning object LO only and is NOT an OLLO. Conceptual model of the OLLO is shown in Figure 2, the core communication architecture of an OLLO is shown in Figure 3. The benefits of developing OLLO's for as much labs as available within the institute is beyond the teaching and learning process, since collaborative research could be significantly fostered when such large database of OLLO's is easily accessible. For further enhancing the collaborative part of an OLLO, video conferencing and editing tools can be added on the top of the OLLO. Laboratories are often developed for providing the students with authentic real experience, if we restrict the OLLO for simulation only as the case of LO's, the developed laboratory learning object will loose the most important motivation behind labs tuition, which is realism.

We used LabView as major tool for developing an OLLO for the process control lab that is used for many courses tuition in the chemical engineering department. We developed a virtual simulated version of the laboratory, which allows student to perform all experiments in a simulation mode using an interface identical with the real operator interface in the lab. A remotely operated version of the lab was also been developed and used in the classroom to illustrate the theoretical concepts on real-life experiments. The OLLO allows remote operation and provides real-time video transmission for creating the feeling of telepresence. The DAQ hardware device we used is a NI USB-6000 series USB data acquisition (DAQ) device worth about 150£. Part of the process control lab OLLO GUI is shown in Figure 4. The developed OLLO has been deployed on the web for internal use only right now but a simulated version can be downloaded and installed as stand alone application from http://www-staff.lboro.ac.uk/~cgzkn/).

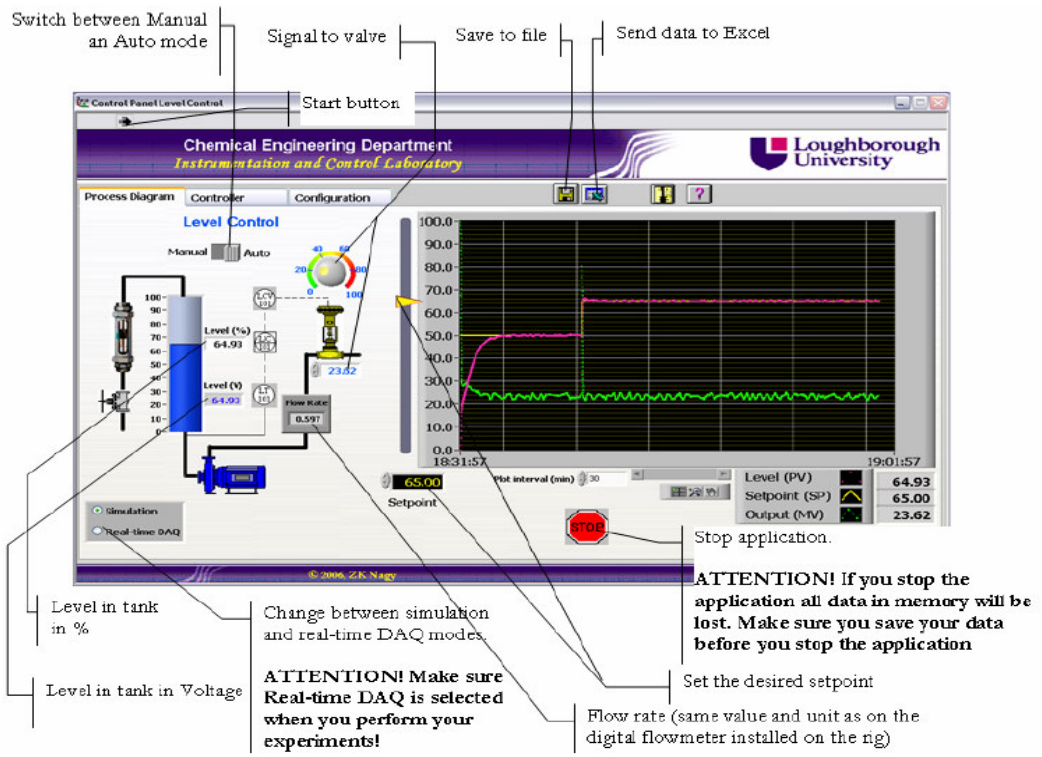
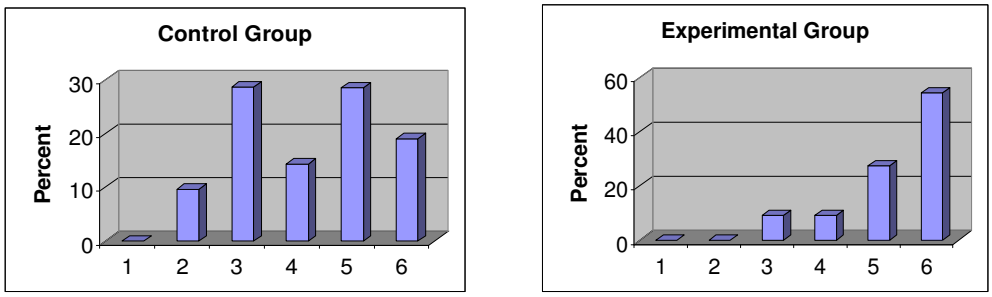


Figure 4. The Process Control Lab OLLO GUI

Educational Utilization of the Process Control Lab OLLO:

The P.C.L OLLO has been used in the master module “Advanced Computational Methods for Modelling and Analysis of Chemical Engineering Systems”. The Module aims to introduce students into topics such as dynamic modelling, optimization, PID control, which are applied to chemical process. In this course. We used the P.C.L OLLO remote operation property in the course exam.



(a) (b)

Figure 5. Answer distribution of the control group (a) and the experimental group (b)

The P.C.L OLLO was also used in a pilot study for the “Instrumentation and Control” course taught for second year students at the chemical engineering department,

Loughborough University. In this course, the OLLO was used in pre lab session for getting the students prepared before they conduct the hands-on experimentation. Some students done the preparation session with the OLLO and some did not. In surveying the students will of conducting extra experimental work, we found that those who did the preparation have got more motivation towards experimenting further ideas after the hands-on session facilitated by remote connection character of the P.C.L. OLLO. The responses of the two groups differed considerably; the average of the control group is 4.19/6 while the average of the experimental group is 5.27/6. Figure 6 shows the answers distribution of both groups (Control group are those who did not use the OLLO).

Furthermore, we found that the experimental group students have got higher conceptual understanding of the theory behind the experiment. We conducted post test quiz right after the lab for the students, the quiz contained many questions with emphasize on the conceptual and the hands-on experience that the students were expected to gain after conducting the lab. The means average in general was higher for most question of the experimental group students. The Hypothesis statistical test revealed a higher difference significance factor for the conceptual questions.

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