

# Beyond The Classroom Walls: Remote Labs, Authentic Experimentation with Theory Lectures

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***Abstract:** Recent calls of constructivist pedagogy emphasize the role of delivering education in more authentic and real contexts. It urges the change of the classical classroom lecture model towards more active participation of the students. Engineering is to large extent an applied science, it is very important to be taught in its genuine context rather than the current more theory oriented model. One important issue is to support the classroom theoretical lectures with real applications. Laboratories are provided essentially as core part of engineering education as a platform of showing the applicability of theory into practice, however, most labs are not portable and can not be moved into the classroom to show the links between theory and practice in real time. One solution is close the distance through remote operation of the lab rig during the lecture. This approach is also useful in enriching the number of utilized rigs through sharing among institutes. This paper reports on the approach of utilizing and sharing remote experimentation for classroom theoretical lectures. It also reports the students opinion towards the novel approach.*

## Introduction

Classroom lectures have been frequently reported to be boring and lack interactivity, many lecturers reported low attendance rate of the students in the lectures, research has shown the students attention to the lecture may drift severely after 10-18 minutes (Johnstone et al 1978). In classical lectures, the students are passively receiving the information the lecturer is delivering, there is mainly load of new theoretical materials delivered without any associated authentic application of the presented theory. This is especially the case in engineering and science lectures, despite the fact that engineering in principle is an applied science. Too much delivered theory may frustrate the engineering students who have selected to study that field mainly because it is an applied science. Many lecturers have been aware of this problem and tried to incorporate authentic applications or experiments in their classroom lectures to lift the students attention again to the inherent character of engineering education and to support the theory explanation by showing its applicability in real life. An engineering demonstration kits in the classroom has been used as old as 1964 (Kingma 1964). Blending electrical and electronics engineering lectures with experimentation is somehow easier than other disciplines due to the small size and low cost of designing experimentation kits, examples from engineering lectures can be found in (Robbins et al 1973; Froehlich et al 1978; Croskey 1990; Zain 1994; Lewin 1999 & 2002, Tittagala et al 2008), many have reported the positive impact of augmenting the classroom theory with experimentation.

The importance of laboratory experience in engineering education curricula has been emphasized in a large number of science and engineering education articles (Johnstone et al 2001; Hofstein et al 2004; Feisel et al 2005; Kirschner 1988; Ma et al 2006). The essential role of laboratories can be correlated with the fact that engineering is, in general, an applied science that requires very good hands-on skills and involves elements of design, problem solving, and analytical thinking. Well designed laboratories during undergraduate engineering degrees can improve these skills of the future engineers. Engineering started as a result of the accumulation of hands-on experiences. It had been taught as a pure hands-on subject up to the 18th century.

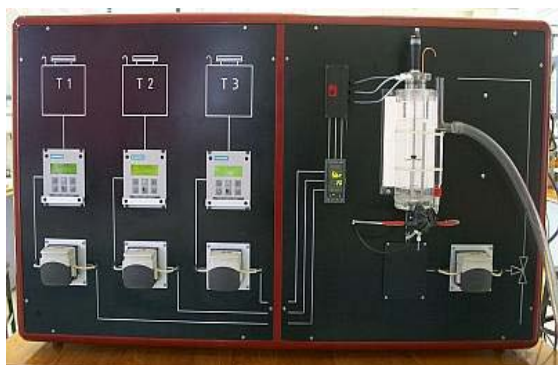
However, engineering education has benefited from the advances in science and it began to embed deeper theoretical concepts by the end of the 19th century, especially in the US schools initially (Feisel et al 2005). Since then, the pedagogical emphasis in engineering education has been shifted more towards classroom and lecture based education, and gradually less attention has been given to the laboratory education, particularly during the last 30 years (Hofstein et al 2004; Hofstein et al 1984; Feisel et al 2002). One important contribution of laboratory education in the engineering curricula is 'enjoyment' as a motivating factor for students, which has been reported in many studies during the last few decades (Hofstein et al 2004).

## Remote Laboratories

The most recent laboratory paradigm is the so called remote or online-laboratory in which students can physically perform hands-on experiments which are located at a place remote to the student, typically via Internet access. The idea of implementing controlled laboratories through the Internet for educational purposes can be tracked back to the 1991 when Aburdene and others suggested a futuristic solution for sharing laboratory equipments through the Internet (Aburdene et al 1991). They expected that this model would be used for operating experiments in the classroom and would be a facilitator for sharing experimental resources among institutions. An implementation of remotely controlled robots which was scattered over four universities in the US and NASA was successfully tested in 1993 (Kondraske et al 1993). Another early application was an Internet based control laboratory which was implemented in Oregon State University (Aktan et al 1996). Since then the number of Internet based laboratories has rapidly increased and the geographic distribution spread to Europe, Australia, and East Asia. One advantage of developing an online laboratory is the ability to share resources with other partners, which eliminates the economic cost of buying new hardware for the institute. Online laboratories shared among many universities could enrich the experiential education of students as they would have a large database of laboratories to access. The cost of new experimental rigs is significant to a higher education institute's budget. This is particularly true in some engineering disciplines where technology is advancing quickly and there is a continuous need to follow and embed these advances in the curriculum. This pressure led in the 1970s and 1980s to a move among some institution administrators to minimize the laboratory work in the undergraduate curricula (Kirschner et al 1988). Many researchers have described the economical benefits of implementing more online laboratories (Kondraske et al 1993; Ma et al 2006). One example of sharing experiments located on two different continents is the Cambridge-MIT remote experiment (Colton et al 2004). Some companies now offer a database of remotely accessed experimental rigs located at different partners to be accessed for a small fee. It has been reported in many papers that online laboratories have stimulated the students enthusiasm towards the studied subject since the labs access was available in a non-conventional way (Aktan et al 1996; Ma et al 2006). There are many other advantages of online laboratories, such as offering real experimentation for distance learning students, accessing remotely hazardous locations or flexibility in delivering laboratory experience.

## Using Cambridge WebLab in Loughborough Classroom

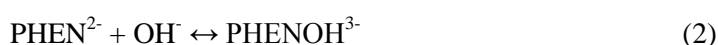
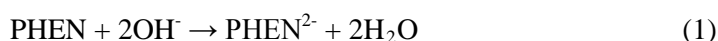
The Cambridge Weblab is a non ideal reactor designed for achieving chemical reaction between phenolphthalein (PHEN) solution and sodium hydroxide solution as follows:



**Figure 1: Cambridge WebLab Rig.**



**Figure 2: Students High Attention**



(pink)                      (colourless)

The solutions are kept in separate tanks, there is third tank of water as well. The tanks solution flow rate to the reactor is controlled via three PID control loops that control peristaltic pumps. When reaction takes place, the reactor colour becomes pink, the colour intensity reflects the PHENO<sup>H3-</sup> Concentration. There is fourth PID loop for controlling the intensity. The Cambridge Weblab shown in Figure 1 has been used in the MSc Module “CGP075 Advanced Computational Methods for Modelling and Analysis of Chemical Engineering Systems” at the Chemical Engineering Department at Loughborough University, the module was organized as part of the new MSc programme in “Advanced Chemical Engineering with IT and Management” started in 2007. The Module aims to introduce the students into topics such as dynamic modelling, optimization, PID control, which are applied to chemical process and to provide them with hands-on experiences in software tools used for implementing the previous techniques, as well as, relevant hands-on control laboratory. The class composed of approx 12 MSc students and two PhD students and the lectures were delivered intensively within one week: 25th-29th February 2008.



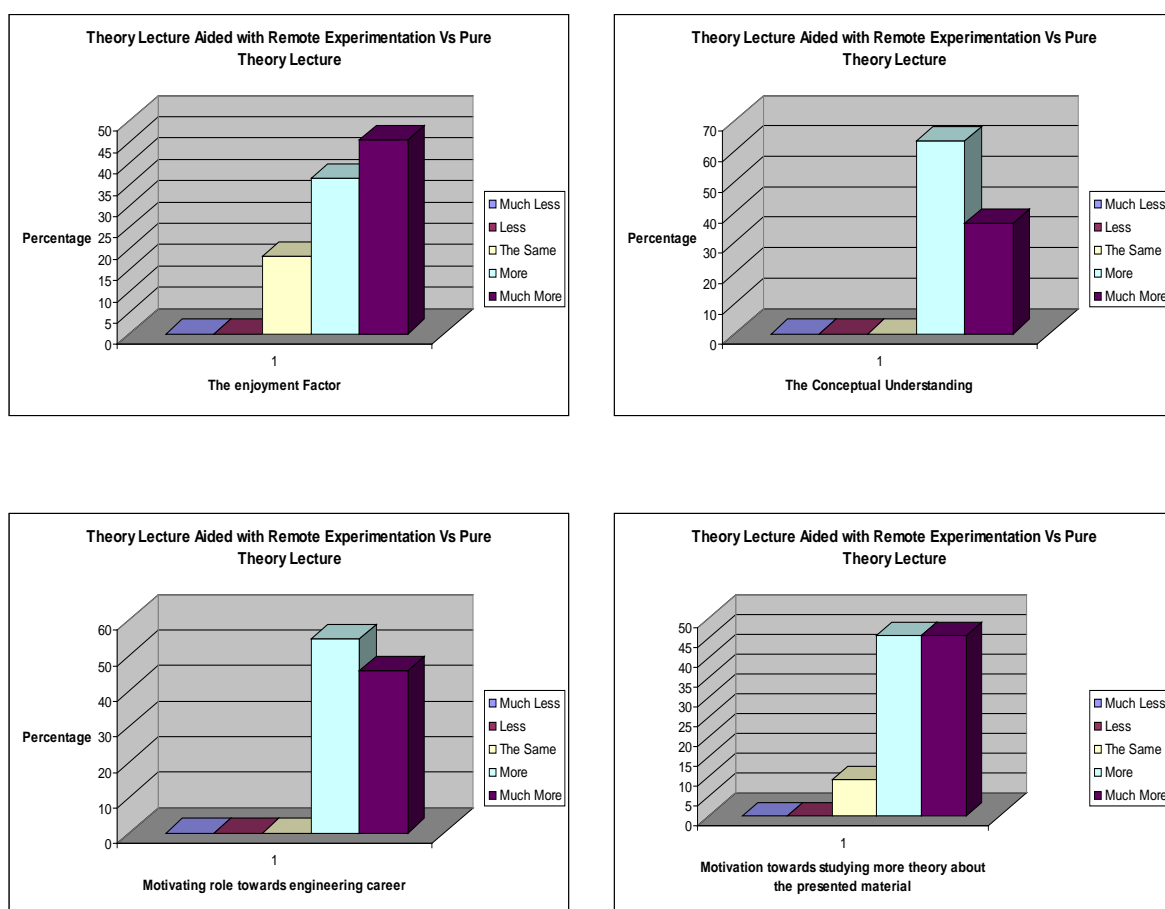
**Figure 3: Students Active Participation**

The Cambridge Weblab was used in a classroom demonstration for supporting theoretical topics in control engineering, in particular, demonstrating the PID control and tuning algorithms. To show the students a real example of remote operation, and real industrial operating interface, which can be found in many industrial plants. The demonstration was also used to get pedagogical measurements on cons. In particular, whether blending classical theoretical lecture with real experimentation improve:

- The conceptual understanding

- The enjoyment
- Motivation towards engineering career
- Motivation towards studying further theory.

After the students were introduced to PID control, we demonstrated them a real application through the remote connection to Cambridge Weblab. To give the demonstration more realism, we projected simultaneously the experimental interface and the live web camera transmission. In this demonstration (1 hour), we gave large space for students to discuss the influence of different tuning parameters. The students seemed to have high attention to the lecture such as shown in Figure 2, they were interesting in trying and testing the theory themselves on the lab. They applied their suggestions in real time, and looked at the outcome such as shown in Figure 3. Interesting argumentation have evolved among the students in this lecture of what is the best P,PI, or PID based on their real observations, the remote experience itself was stimulating for the students. We used the electronic voting system devices in the lecture (Turningpoint 2008) to evaluate the students understanding immediately in the lecture where the students have to answer multiple choice questions



**Figure 4: Students Attitude Towards Blended Lecture**

Their answers are collected and analysed through the voting system hard and software and a quantitative representation shows up immediately after they have answered, the voting system have been used in other lectures as well during the module. In general, they scored higher in this session than their answers in the other purely theoretical lectures.

To measure the difference between blended lectures and purely theoretical lectures, we asked the students their opinion on many issues of concern for engineering educators such those represented in

Figure 4. The students have found blended theoretical lecture with real experimentation compared to purely theoretical lecture:

- More enjoyable!
- More understandable.
- More motivating towards continuing engineering.
- More motivating towards investigating further related theoretical information.

The students had positive attitude towards embedding classroom experiments in other courses as they found this approach more helpful on understanding theory.

Some difficulties in teaching control systems engineering are due to heavy dependence on mathematics which is mere abstracts when not connected to real examples. Supplementing this theory with real experimentation seems to justify the taught mathematics and transform the abstracts into a lively experience. For instance in this particular case, PID control, it shows the mechanism by which the PID controller mathematical algorithm is responding to the output differences from the set point. We think this is associating the students abstract cognition of the mathematical equations with additional visual/kinetic cognitive axes, hence the students are receiving information through two channels instead of one; the dual coding theory argues of enhanced cognition is such a case (Slavin 2006). More importantly, we think that engineering students are more accustomed to the visual/kinetic cognition than abstract cognition, hence, the interpretation that they find such approach more enjoyable, understandable.

Frustration in the theory lecture plays essential role in demotivating the students towards the taught subject and impacting badly on their future career. When students understand theory well, constructively interact with each other, and further more, apply it themselves simultaneously, the frustration will demolish and the motivation may emerge. The students attitude measurements of combined theory and authentic experimentation is supporting this argument.

## Conclusion

Developing remote version of a currently available hands-on lab would have relatively lower cost compared with the initial hands-on lab cost. Yet the low cost, remote labs offer unique chance of sharing among institutions and enriching the engineering education. It opens the door for new pedagogies such as classroom theory augmented with real time presentation of its applicability in authentic experiment. We used the Cambridge Weblab in postgraduate teaching in the classroom, the approach approved positive impact on the students during the lecture, however, it have limited somehow the theory devoted time, the streamed video of Cambridge test rig played essential role in validating the experiment authenticity. Such positive attitude maybe related to the fact that augmenting lecture with real experimentation have lead to enhanced cognitive perception. Most of the students reported enhanced motivation towards engineering career and further theory study. Further investigation is recommended to measure the real learning outcome of theory vs. theory/experimental lecture, and how deep is this learning.

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