Chapter 21
Technology-Enhanced Laboratory Experiments in Learning and Teaching

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ABSTRACT
Laboratory practice plays a crucial role in engineering and technology education. The advancement of computational and computer technologies have ushered in a new horizon in learning and teaching of laboratory practices worldwide. Apart from traditional hands-on laboratory practice, two other laboratories, namely the virtual/simulated laboratory and the remote control laboratory practices, are playing an increasingly dominant role. The virtual and remote laboratory practices offer unique opportunities for students to visualise complex concepts and remove the time and location barrier. This chapter provides a comparative analysis of all three laboratory practices. Additionally, a 3-step laboratory practice and a hybrid laboratory practice developed at RMIT University are described. It is evident that the advancement of computational technology enhances the student learning experience in laboratory practices. However, real world hands-on laboratory practices cannot be fully replaced by the virtual/simulated and/or remote control laboratory practices. They are complementary.

INTRODUCTION
Engineering is a profession devoted to devising solutions to real world problems. The laboratory practices, as an integral part of engineering and technology education, prepare students to apply theoretical knowledge into practice and to extract data necessary for a design, to evaluate a new device, or to discover new knowledge. The fundamental objectives of a laboratory practice are the cognitive learning (integration of theory with practice), inquisitive learning (hypothesis
development, design of experiment and methodology, and evaluation of data, results and findings), vocational learning (awareness of current practice and inculcation of professional ethics), and communication learning (communication, presentation, report writing and team work skills). Laboratory practices can also assist students to develop critical enquiry and problem solving skills (Edward 2002). The significance of hands on practical (laboratory) knowledge in engineering education has been strongly emphasised by academic staff and well reported in the literature (Chu & Lu, 2008; Corter et al. 2004 & 2011; Dechsri et al. 1997; Feisel & Rosa, 2005; Hofstein & Lunetta, 2004; Johnstone & Al-Shuaili, 2001; Kirschner & Meester, 1988; Lemckert, 2006; Ma & Nickerson, 2006; Tan et al. 2000). A hands-on laboratory enhances a student’s ability to apply theory into practice and also shows where there is a discrepancy between theory and practice. The data obtained from a laboratory practice and the data obtaining procedure are clear demonstrations of the ability and the limitation of scientific theories (Corter et al. 2004). Today, the pedagogical emphasis in engineering education has shifted more towards theory-based education using information and communication technology (ICT) (Abdulwahed and Nagy, 2011).

The traditional hands-on laboratory practices/experiments involve physical presence of academic staff, physical equipment and software (where appropriate) that provide students a feeling of realism with the sense of dealing with a real world situation. Researchers emphasise the importance of an authentic and real or quasi real environment for learning and teaching (Richardson, 2003). Hands-on laboratories are particularly important for acquiring practical design and instrumentation skills. These skills are difficult to obtain via virtual/simulated or remote laboratory practices (Abdulwahed, and Nagy, 2011).

It is beyond doubt that acquiring knowledge is a complex process that can be beyond the time frame of the scheduled hands-on laboratory practices as the learning is an iterative process (Hmelo et al. 2000; Kolb, 1984; Papert, 1980). In order to enhance the learning experience in laboratory practices, students need to reflect and provide feedback (Hofstein & Lunetta, 2004 & 1982). Such features are generally missing in traditional hands-on laboratory practices primarily due to limited allocation of time for students (Kirschner & Meester, 1988). Hands-on labs are usually taught as one single demonstration to students in a group for economical and logistical reasons. However, in-depth understanding of a concept requires more than a single, short demonstration.

The importance of laboratory practices is more paramount for engineering especially mechanical engineering students to work effectively and to compete globally. Generally, mechanical engineering education requires hands-on practical equipment, workshop facilities, technicians, ongoing maintenance and regular upgrading. Today industry and research organisations want work ready graduates with hands-on practical and theoretical knowledge so that the graduates can work effectively immediately after their graduation with little formal induction or training.

In the past, most universities in the developed world could afford such expensive infrastructure for mechanical engineering students whereas most developing countries’ universities fell notably behind in this context due to the shortage of funding and resources. Presently, most western universities are under immense financial pressure due to funding cuts by governments in education sectors especially at the tertiary level. Mechanical engineering programs are hit hard and forced to find alternative ways to deliver the practical education by reducing or replacing physical laboratories. Many mechanical engineering departments/schools have been forced to reduce their expenditures on capital equipment as well as operating, maintenance and staffing costs (Chowdhury and Alam, 2012; Alam et al. 2007 & 2004; Chu and Lu, 2008). Additionally, a smaller class size (~60 students) a decade ago has now become