Chapter 14
Low-Cost Virtual Laboratory Workbench for Electronic Engineering

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ABSTRACT
The laboratory component of undergraduate engineering education poses challenges in resource constrained engineering faculties. The cost, time, space and physical presence requirements of the traditional (real) laboratory approach are the contributory factors. These resource constraints may mitigate the acquisition of meaningful laboratory experiences by students, which is especially true in developing countries. Virtual laboratories can be used to complement the traditional laboratory to enhance students’ laboratory experience. In extreme cases of lack of resources, the virtual lab can be used as an alternative laboratory. Although some research on the implementation of virtual laboratories has occurred, more efforts are required because of the diverse experiential needs and requirements of the engineering curriculum. This paper presents a low-cost, web-based virtual laboratory workbench for use as part of undergraduate electronic engineering courses. Some distinguishing features of the virtual workbench are that students can undertake curriculum-based laboratory activities in a realistic manner; it integrates a Bayesian Network-based assessment structure for the assessment of students’ performance; and it affords the instructor flexibility in designing laboratory exercises.

INTRODUCTION
Laboratory activities are crucial components of engineering education. Some of their benefits in engineering education include: helping students to deepen their understanding of taught concepts through relating theory to practice; and motivating students’ interest in a subject (Davies, 2008). Computer Aided Learning (CAL) tools can be used to enhance laboratory learning in various ways. Advances in web and computer technologies continue to facilitate the provision of improved...
laboratory learning and experimentation. CAL tools provide improved environments for laboratory education that are comparable to and in some cases better than the traditional method (Li, 2005).

Virtual laboratories are CAL tools that can provide laboratory learning environments in a wide variety of forms and formats beyond the limitations of the traditional laboratory. Research evidence has proven the effectiveness of virtual laboratories in enhancing students’ laboratory learning and performance (Campbell et al., 2002). In some cases, the evidence contradicts popular hypotheses that physical presence and face-to-face instructor-student interactions provide more valuable experiences and produce better learning results.

Although virtual laboratories have proven useful in many areas of education, their use in engineering laboratory education is still a challenge because of numerous experiential requirements. Thus, for various fields of engineering, research is on-going on virtual laboratories that can emulate the traditional laboratory processes. The aim is not to replace the traditional laboratory with virtual laboratories but to complement it (Mannix, 2000). Virtual laboratories provide meaningful laboratory experiences (Davies, 2008) and also serve as alternatives in extreme cases (Budhu, 2002). This is because they can be used to provide meaningful laboratory experiences (Davies, 2008).

Presently, the Internet is widely utilized as a platform for web-based virtual laboratories. This paper presents a web-based virtual laboratory workbench with which electronic engineering undergraduate students can undertake curriculum-based laboratory activities in a realistic manner. The workbench has a wide curriculum scope and is not limited to a single area or level of application, thus affording instructors flexibility in designing laboratory exercises. In addition, the virtual laboratory incorporates a Bayesian network-based laboratory performance assessment model for assessing students’ laboratory activities from a holistic perspective.

**MOTIVATION**

In the early years of Electrical and Electronic Engineering (EEE) degree programmes, undergraduate students face the challenge of grasping the fundamental concepts taught in lectures. In universities offering a 5-year undergraduate EEE programme such as the Federal University of Technology, Owerri (FUTO), Nigeria, all the EEE students offer the same course units in their first three years of study. During this three-year period, the students are exposed to the foundations of science and general studies, fundamental EEE course principles and circuit theory. Laboratory activities are concentrated mainly in the second and third years of study. At the end of the third year, students choose their preferred EEE course options: Communication Engineering (COE), Power Systems Engineering (PSE) and Electronic and Computer Engineering (ECE). As the students enter into their fourth and fifth years of study, they concentrate mainly on course units for their respective options. At this level, they begin to apply the fundamental concepts learnt in their earlier years to specific problem contexts.

Research has shown that students find it difficult to grasp the fundamental concepts taught in the early years of EEE degree programme (Gilbert, 2003). Laboratory activities can be used to enhance students’ understanding of concepts taught in lectures. However, laboratory education can present a number of challenges to engineering faculties, especially those in developing countries which often lack meaningful laboratory resources because of resource constraints and students often far outnumber the available laboratory equipment. The severity of these challenges in developing countries is such that some students may graduate without the opportunity for meaningful laboratory experiences. The cost, time, space and physical presence requirements of the traditional engineering laboratory approach are major contributory factors to these challenges. A web-based virtual
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