

# Chapter I

## The Modular Design of an Internet-Based Laboratory

**Abul K. M. Azad**

*Northern Illinois University, USA*

### ABSTRACT

*This chapter presents the development of a modular Internet-based laboratory facility using cutting edge technologies along with its implementation for offering a laboratory course. The modules are developed using commercial products and are adaptable with a variety of laboratory experiments with little effort or maintenance cost. The developed facility has in-built capability to collect systems' operational data that are used to evaluate the effectiveness of the system and assess the students learning behavior. Provision was also made to assess the level of learning while using the facility. An Internet-based laboratory facility involves real laboratory equipment controlled remotely over the Internet that enables students to get access to laboratory equipment any time from any location, where most laboratory equipment is idle for a major part of its working life. Having these advantages, there is very little effort or interest within the academic community to implement the Internet-based laboratories for course offerings due to the complexity of operation, complicated design, extensive maintenance effort, higher implementation cost, lack of human interactions, and ethical issues. To address these problems, the author has developed this modular Internet-based laboratory facility and studied its performance through a laboratory course.*

### INTRODUCTION

*Traditional Laboratory Facility:* Traditional laboratory classes are scheduled only for a limited time period. Considering the mixed ability level of students, the allocated time is often not

enough for all students to complete their tasks satisfactorily and also gain sufficient experience through the process (Boyle, Bryon, & Paul, 1997; Grose, 2003). Sometimes students also want or feel a need to perform additional experiments beyond their assigned tasks. It is difficult to accommodate

such extra experimentation because universities often lack resources to keep their laboratories open (Bengu & Swart, 1996). Additionally, laboratory facilities are usually inaccessible to the students of other departments within the same institution because of their geographical location. Ironically, too much laboratory equipment lies idle during most of its usable lifetime (Palais & Javurek, 1996). An Internet-based laboratory facility would address these problems by providing unlimited access to an experiment and hence maximize the use of available resources.

**Limitations of Internet-based education in terms of laboratory facility:** One of the major limitations of existing Internet-based distance-learning courses is their failure to deliver the laboratory-related courses (Swearengen, Barnes, Coe, Reinhardt, & Subramanian, 2002; Vohra, 2002). While simulation and multimedia provide a good learning experience for effective and complete learning, especially in applied engineering and technology programs, a mixture of theoretical and practical sessions is needed. Currently, students have to visit a campus to perform the laboratory sessions for these kinds of courses, or there has to be an arrangement of mobile laboratories stationed at a few predetermined locations for a given period of time (Henson, Fridley, Pollock, & Brahler, 2002). With such arrangements, students get access to the hands-on facility for only a short period of time, which is usually insufficient to allow them to complete their learning process. Making the laboratory experiments accessible through the Internet would address this need.

**Benefits of Internet-based laboratory facility:** In addition to being a part of a distance-learning program, the Internet-based laboratory facility can also be used to complement the traditional laboratory classes. The Internet has already proven to be effective in preparing rural and inner-city high school students where there is no provision of advanced placement courses. It enables them to compete with other students in top colleges and move toward bridging the digital divide (Hagg & Palais, 2002). An Internet-based laboratory would

allow them to perform laboratory experiments to enhance their theoretical knowledge and better prepare them for college. The Internet-based laboratory facility may allow students to familiarize themselves with experiments before proceeding to actual laboratory sessions. This kind of facility, either as replacement or supplement of traditional laboratories, has valuable benefits by allowing a more efficient management of the laboratories as well as facilitating distance-learning programs.

Moreover, this will allow for interlaboratory collaboration among universities and research centers by providing research and student groups access to a wide collection of experimental resources at geographically distant locations. An added benefit is the reduced costs incurred when different educational departments and institutions share facilities, since automated, remotely accessible systems are more cost effective than scheduled laboratory sessions conducted by salaried assistants and technicians, not to mention the cost and effort needed to maintain the laboratories.

**Current status of Internet-based laboratory facility:** A number of attempts have been made to provide students and researchers with practical exercises or experimentation experience over the Internet. In this light, some of the initiatives toward the development of laboratory experiment are discussed. In two cases, researchers have developed experimental demonstrations in which robots can perform a few simple manipulations from a distant location over the Internet (Fletcher, 2004; Kamrani & Salhieh, 2000). Implementing these demonstrations required the development of a complex system. Iowa State University, meanwhile, has developed an experimental facility to train K–12 teachers (Chumbley, Hargrave, Constant, Hand, Andre, & Thompson, 2002). This facility provides hands-on experimental experience with a scanning electron microscopy (SEM). Considering the cost of an SEM, it would be impossible to provide this training without the Internet-based experiment facility. However, implementation of this experiment was quite

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