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A model for evaluating the effectiveness of remote engineering laboratories and simulations in education

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Abstract

Economic pressures on universities and the emergence of new technologies have spurred the creation of new systems for delivering engineering laboratories in education, in particular simulations and remote-access laboratory systems. Advocates of simulation argue that physical labs needlessly consume university space and students' time. However, proponents of hands-on laboratories argue that student engineers should be exposed to real environments. Remote laboratories have appeared as a third option. These laboratories are similar to simulation techniques in that they require minimal space and time, because the experiments can be rapidly configured and run over the Internet. But unlike simulations, they provide real data. Studying the relative effectiveness of these modes of delivering student laboratories is complex, for the underlying technology of the laboratory is just one of many possible factors that could influence effectiveness. For example, the interface to the equipment may be of importance, as might the discussions students have among themselves. This paper presents a model for testing the relative effectiveness of engineering laboratories in education that takes account of these and other factors. The results are presented for an assessment study comparing versions of remote labs versus hands-on labs in a junior-level mechanical engineering course on machine dynamics and mechanisms. The results suggest that students learned lab content infor-

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mation equally well from both types of laboratories, and that they have a realistic understanding and appreciation of the practical advantages of remote laboratories.

Keywords: Computer-mediated communication; Presence; Educational assessment; Remote laboratories

1. Introduction

Many educators have strong feelings about the relative merits of different technologies to be used in engineering laboratories, and these educators disagree with each other. The argument is significant because it is clear that the choice of laboratory technologies could change the economics of engineering education, and it is also clear that changing the technology could change the effectiveness of education (Canizares & Faur, 1997; Ertugrul, 1998; Finn, Maxwell, & Calver, 2002; Magin & Kanapathipillai, 2000; Willams & Gani, 1992). These positions are often debated in comparing types of student laboratories that differ in their modality of delivery, namely traditional hands-on laboratories versus remotely-access laboratories versus simulations. Hands-on adherents think that engineers need to have contact with the apparatus and that labs should include the possibility of unexpected data occurring as a result of apparatus problems, noise, or other uncontrolled real-world variables. Adherents of simulation point out the high monetary, space and time requirements of hands-on labs. Setup and teardown time may be greater than the actual experiment performance time. They claim that simulation is not only cheaper, but it is also better, in that more laboratories can be conducted than with hands-on laboratories. However, there is a third alternative to be considered, namely remotely operated laboratories (Alamo et al., 2003; Gillet, Nguyen, & Rekik, 2005; Harris & Dipaolo, 1996; Henry, 2000; Nedic, Machotka, & Nafalski, 2003). They require some space, but less than a hands-on lab. They use real data, but the data is acquired through the mediation of a web interface. They are relatively inexpensive to operate.

Researchers have pointed out that the practical work of laboratories is subject to constraints. There are the constraints of physical facilities and scheduling that universities face. Also, there are constraints on what students can do; for example, students with disabilities may have less of a chance than other students to interact in laboratory environments. Thus, remote laboratories may not only satisfy the economic needs of universities, but also may be convenient for able students and an important facilitator for disabled students or students who for other reasons must take courses remotely (Colwell, Scanlon, & Cooper, 2002; Scanlon, Colwell, Cooper, & Di Paolo, 2004).

This debate over hands-on versus simulated or remote laboratories is similar to the debate surrounding rich media. As telecommunication established itself as a medium for doing business, both employees and employers became interested in telecommuting. They wondered if remote work might be just as effective as work in an office, and might be more convenient for the employee, and less expensive for the employer. Psychologists began studying how communication mediated through technology was different than face to face communication (e.g. Short, Williams, & Christie, 1976). Some researchers have presented evidence that face-to-face communication is preferred when situations are by their nature ambiguous (Daft & Lengel, 1986). Others have