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AUTHOR	Alhalabi, Bassem; Hamza, M. Khalid; Hsu, Sam; Anandapuram, Sudeep
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ABSTRACT

This research explored the challenge of how students might successfully perform real laboratory experiments over the Internet without being in a laboratory. Numerous distance learning environments were surveyed, and the effectiveness and disadvantages of laboratory facilities currently available over the Internet were assessed. Full and part-time virtual laboratory programs of prominent universities in North America and the United Kingdom were examined, as were pure virtual universities that have no established campus structure. Research revealed that existing labs that were promoted as virtual environments were merely software simulations that were far from authentic lab experimentation. Hence, the researchers created an environment that renders remote performance of genuine lab experiments, or genuine remote experiments (GRE). Advantages of GRE, interactive breadboarding technology, and system design are highlighted. (Contains 16 references.) (MES)

Virtual Education: Reality or Virtuality?

Bassem Alhalabi, Ph.D.

M. Khalid Hamza, Ph.D.

Sam Hsu, Ph.D.

Sudeep Anandapuram, MCE

Florida Atlantic University, CSE Building. Boca Raton, FL 33431
Tel: (561) 297-3182 Fax: (561) 297-367-2800 E-mail: bassem@cse.fau.edu
Center for Distance Education Technologies (CDET)

Abstract: For years, many nations have enjoyed technological innovations used in building computers, computer architecture and design, and computer mediated communications. American institutions of higher education have also enjoyed these advancements through successfully establishing Net-based curricula. Success, however, have been limited. Therefore, how might students successfully perform real lab experiments over the Net without being in a laboratory? To explore this challenge, the researchers surveyed numerous DL environments and assessed the effectiveness and disadvantages of laboratory facilities currently available over the Internet. Research revealed that coexistent labs that were promoted as virtual environments were merely software simulations and, at best, created software simulations were far from authentic lab experimentation. Hence, the researchers created an environment that renders remote performance of genuine lab experiments, or genuine remote experiments ("GRE").

1. Introduction

Research suggests that most of the tools employed to train students over the Internet are simulation software, also known as "Virtual Labs." The term "virtual" indicates that the university campus may or may not physically exist. These types of universities offer comprehensive degree programs that deliver course materials through online communications. In most cases, these universities offer the same primary tools of learning as do established universities that offer distance education programs. Hence, virtual universities have emerged as equally acceptable alternatives to conventional universities.

In such environments, the knowledge gained by the student is limited by constraints, boundaries, and other capabilities offered by the manufacturer's simulation software. The examination of literature, existing distance education web sites, and surveys indicate that students are free to perform experiments only in "limited environments" through the programmed design of the software. Hence, these constraints do not permit creativity to flourish, nor do they permit a student to experiment in natural settings where the involvement of human perception fosters learning skills.

This paper suggests an allowable, creative learning environment where authentic lab experiments may take place via the Internet and where students have the unconditional freedom to apply input and feedback of output results as though they attended the experiment in-person. The implementation of the idea is technologically conceivable from recent innovations of fast-prototyping breadboards that allow the building of complex electrical systems from discrete components without the use of wires. At that point, all system wiring (and any future rewiring) are performed via the host computer by the click of a mouse without touching the board. Unlike software simulation, this engaging technology is intended to accommodate high-end fast prototyping and true hardware emulation.

2. The Internet: Planet Information

The Internet's boundless, polymorphous resource of media-based information connects over 25 million people from roughly ninety countries through a massive computer network (Harasim, Hiltz, Teles, & Turloff 1995; Hirumi & Bermudez 1996). Therefore, administrators of institutions of higher education are attracted to expand instructional resources via diverse distance modalities.

During the pioneering of the Internet, its potential was recognized early on as the most dynamic tool in distance learning. (Turoff 1994). The wealth of information that the Internet holds, the constant updates and the ease of transmitting information instantaneously in addition to its cost-effective methods of reproduction, produced a tremendous impetus to make use of what was until then an unattractive, scarcely noticed, mode of distance education (Hirumi & Bermudez 1996; Gaines 1996). Regardless of the costs involved in using Internet technology, few educators seem concerned with the ways that the Internet might assist educational need and learning process as a meaningful, cognitive learning tool. We must ask the following: What instructional strategies and objectives underscore the use of this newly implemented technology? Will this technology assist, enhance, or promote learning? As educators, what do we seek to foster in students?

3. Distance Education: The Tools

Without doubt, the Internet evoked an Educational Renaissance (Jones 1997). As ever-increasing numbers of knowledge-hungry students bore the costly expense of ill equipped on-campus studies, this reawakening in the sharing of information popularized distance education due primarily to outreach and convenience of self-pace (Ferrate 1997) and made learning more affordable to larger numbers of learners (Ayersman 1996). Today, distance education offers varieties of courses that cover nearly every area of study offered by on-campus programs (Walsh 1995) and its annual market of over $8.25 billion *()* attracts some of the world's finest universities.

Fundamentally, the method of teaching adopted in virtual education can be classified as synchronous or asynchronous in that each approach offers a unique advantage (Gibbs 1997). Synchronous teaching contributes to collaborative learning through joint problem solving scenarios and can be used in threaded discussion through active participation of the guide or teacher. Asynchronous teaching frees students from the anxieties associated with group learning and permits self-paced study through repetition (Aotani 1997).

Despite these successes, other specialized fields remain far from ready for online dissemination. Laboratory sessions are vital to engineering curricula, yet today's distance technologies are insufficient in allowing students to complete degree requirements without physically engaging the lab facilities. Software simulations have become the leading solution to this challenge; they enable students to comprehend study materials because greater time allowance permits easy-to-use tools. Software simulation used in "performing" engineering lab experiments via the Internet fostered the establishment of web-based engineering curricula, although the quality of education remains incomparable (Harasim, Hiltz, Teles, & Turoff 1995). How to install GRE on the Internet, therefore, remains the challenge.

4. Survey of Existing Virtual Laboratories on the Internet

Full and part-time virtual laboratory programs of prominent universities in North America and the United Kingdom were examined, as were pure virtual universities that have no established campus structure *()*. Over 80 accredited universities offer more than 2700 distance education courses; although not all of these universities offer laboratory supplements, more than 95% of all providers restrict their curricula to virtual classrooms. The others offer online laboratory courses. However, only the Open University in Great Britain *(;* Van Gorp & Boysen 1997) answered the challenge of providing lab courses over the Internet. Nevertheless, few solutions followed (Alhalabi, Anandapuram, & Hamza 1998).

GRE & Distance Learning

In specialized courses such as Logic Design, Microprocessors, and Electronic Circuits, hands-on laboratory experiments are crucial to understand basic concepts. Describing an experiment or even watching the process being performed by another falls significantly short of the requirements necessary for proper education (Harasim, Hiltz, Teles, & Turoff 1995). Four current alternative methods that provide "lab experiment" settings are videotapes, home experiment kits, student site facilities, and simulation software (Harasim, Hiltz, Teles, & Turoff 1995). Among these four schemes, field literature indicates that simulation software is the best alternative, because it is easily transportable and cost effective (Gorrel 1992; Thomas & Hooper 1991). The researchers confer, however, that simulation software provides least hands-on experience.

Sending videotapes to students through the mail is probably the most economical method to display GRE off-campus. The Open University in Great Britain (; Van Gorp & Boysen 1997) and Cornell University of Medical Research are academic institutions that use this method. If the demonstration of a simple experiment satisfies the requirement to reach the student in full measure, the program administrators mail a videotape of the experiment to the student. Following this process, an online examiner assesses the student's comprehension of the subject matter by propounding a number of probing questions (Harasim, Hiltz, Teles, & Turloff 1995). Although this method may help students to understand the concept behind an isolated lab experiment, it surely does not deliver the experimental portion of the lab that hypothecates what would happen if input "x" is changed to value "y."

If hands-on experience is deemed essential to course instruction, a specially designed home kit is mailed to the student with accompanying information that instructs the student how to use the kit. The Open University (), for example, designed several kits for courses such as the electronic circuit laboratory (Harasim, Hiltz, Teles, & Turloff 1995). For example, when teaching the highly technical courses of Advanced Logic Design and Microprocessors, the process becomes cost-prohibitive and nearly impossible. Despite the sophistication of the home kit materials, the student may still not have the accessory computing facilities needed to use the kit. Further, the constraints of time and availability may deter the student from accepting these types of courses that offer this option. This method is more practical and delivers hands-on experimentation, but it is not feasible for use in remote geographical areas or in advanced classes.

The third and, perhaps, best choice is to make GRE facilities available near the student site. Although students take classes (theoretical material, exams, etc.) via the Internet, they perform experiments in physically situated laboratories. Alternately, the university can make laboratory facilities available for a week or two on its campus. Intensive laboratory activities during this period helps students so that they may complete the requirements there or in their homes (Harasim, Hiltz, Teles, & Turloff 1995). This method is by far the most satisfactory to the student, but might be unaffordable in terms of travel. In addition, it might be difficult for university staff to open the facilities for such a short duration. These difficulties potentially disrupt the schedules of students who regularly attend the campus. None of the universities surveyed in this paper use this method.

Very few universities offer comprehensive laboratory courses over the Internet, although the Open University at Great Britain has made tremendous progress toward establishing "virtual laboratories." Michigan State University (online Instrumentation Lab, http://www.vu.msu.edu/previews/tc491d) and Harvard University (Psychology Laboratory, http://icg.fas.harvard.edu/~psych17/) offers its students introductory simulation-based virtual lab facilities (Alhalabi, Anandapuram, & Hamza 1998).

Simulation software is one method that imparts practical knowledge by allowing the student, in performing the experiment, to simulate all the steps on the computer that he or she would make in a laboratory's physical environment (Thomas & Hooper 1991). The intended design of simulation software is to deliver practicable, user-friendly laboratory facilities to the student's doorstep (Gorrel 1992). Continual upgrades in software have made aggregate improvements in the domain of distance learning education (Thomas & Hooper 1991). In recent years, the Multiverse Project () developed student-friendly software that provides step-by-step explanations of lab assignments and expected results. Software available in WEB/JAVA has, to some extent, met these requirements but is not devoid of shortcomings. This practice has yet to achieve broader acceptance, although some universities offer these options despite the obstacles.

Simulation software introduces an element of fiction; at best, it might only produce an approximation that may yield erroneous results. Therefore, the student's comprehension of the experiment will depend more highly on the quality of the software than on the comprehension capability of the student. A simulation is not a proper substitute for a real experiment; the design depends largely on the student's perception as anticipated by the designer. The procedures might be more advanced than what the student can capably perform; one step out of sequence renders the exercise futile. As such, the results of experiments conducted through simulation software must be programmed for use within distance learning parameters; therefore, the student must adhere to prescribed inputs that deny significant freedoms to experiment with disparate criteria. The excitement and interest that accompany GRE experimentation may become nearly absent in simulated environments; such antiseptic conditions may fail to stimulate the student's curiosity. Therefore, the student is more likely to rush through proscribed steps to arrive at the ultimate results. Curiosity is significant because it kindles interest; lack of curiosity by the student typically evokes listless behavior. Therefore, there are no answers to "what if," because the student simply cannot attempt them.

Throughout most colleges, the numbers and types of experiments change from semester to semester. New experiments that accompany each semester's revised syllabus also require content revision, which is often cost-prohibitive and time-consuming. A student who clearly understands the goal of the software at the beginning of the experiment is more likely to produce better results than the student whose understanding falls short. Undesirably, software proficiency becomes tantamount to student proficiency.

5. GRE: Distance Education Ultimate Modality

GRE experiments stimulate higher order thinking skills; GRE environments involve the student's individual senses and learning abilities that foster the learning process. Teaching a student through simulation modalities might assist the student in meeting the course requirements but, ultimately, the student might be incompetent in repeating the experiment in a GRE. Conversely, Real Lab software is designed to bridge those needs. The element of reality is included within GRE environments to remove the student as a passive observer and involve the student as a learner.

6. The Chiller: GRE Online

Originally intended for industrial electronic fast-prototyping and true hardware emulation, the implementation of GRE is technologically possible through recent achievements in interactive breadboarding that investigates unexplored territory in software simulation and allows the wireless construction of complex electrical systems. In the real lab, students are merely rewiring the breadboard, staging the input, and observing the resulting output when they use breadboards to mount Logic Design chips, AND, and OR gates as they connect the chips with wires. Then, the students connect the board to the power supply and observe whether the circuit is functional; if it is not, the students will rewire the board and run it again. If these three actions are performed remotely, the online GRE is successful.

Because the first and third actions are simply the I/O part of the experiment, a standard computer interface with the proper instrumentation device and with an Internet connection can perform these I/O operations. The use of a host computer, however, should not be confused with software simulation because students are still manipulating physically working electronic parts and still have the freedom to make any connections they choose in these lab experiments.

The second action of wiring and rewiring is the challenge. How could students perform the physical act of changing wires on a breadboard without touching it? Standard breadboards are replaced by special interactive breadboards whose pins are connected to a programmable interconnect network controlled by a local computer with a proper software interface. A connection between any pin to any pin is accomplished by a click of a mouse on the software interface.

7. GRE: Instructional Technology and Academic Quality

As the complexity of the digital world deepens, learning institutions that adopt GRE will be able to afford such high-tech tools. Unlike time-shift instruction (experiencing instruction following the live lesson, i.e., videotape, or a software simulation), GRE or real-time instruction (experiencing instruction at some point during the live lesson or experiment) are much more effective and allow students to receive instructions without the teacher's direct presence.

GRE via the Internet furnishes state-of-the-art research environments by utilizing breadboards with programmable interconnecting networks where students at various academic levels can perform complex system experiments without lengthy delays or the high cost of Printed Circuit Boards (PCB). In addition, time-sharing advantages allows many students to concurrently utilize the same breadboard. GRE instructions are based on the principals of Instructional Systematic Design (ISD) the systematic, reflective process that is vital to making learning environments more creative and effective and is used in translating the principles of distance education, learning, and instruction. These processes are used in complement with the plans of GRE instructional materials, activities, information resources, presentations, process evaluation, and revision (Smith & Ragan, 1999). The ISD process is essential in remote distance education and in carrying out effective GRE instructions where students have minimal face-to-face contact with the teacher and may never step into a classroom or a lab. The Real Labs' ID process follows:

8. Conclusion

Software simulation for academic courses that do not require lab experiments, i.e., history, can meet the needs of learners. Experiments are arranged by two categories: 1) those designed to characterize theoretical concepts to the student through the experiment, and 2) those that are designed to substitute actual experiments where the outcomes depend largely upon various experiments that the student performs. Flexibility during the experiment, the main idea behind GRE, is a perquisite to fostering cognitive and intellectual skills (Barbra 1993). Therefore, experiments that students conduct in real laboratories tend to stimulate curiosity and intensify all types of learning skills. While simulation packages contribute significantly to distance education, they can never replace the need for GRE where students are able to construct their own knowledge and set theory and practice to a real test. Hence, the authors of this paper believe that the idea of GRE could be a vinculum to online laboratories of learning excellence.

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