An Interactive Internet Laboratory

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Need for Remote Laboratory Capability

Distance learning systems have mostly facilitated delivery of course content information and laboratory demonstrations. Typically, many community college students are older, have families, have part and full time jobs, some may travel great distances, and some may be enrolled part-time. For them a distance-learning laboratory would make full time enrollment possible and perhaps accelerate their graduation.

Alternative Strategies for an Interactive Internet Laboratory (IIL)

Two strategies for implementing an Interactive Internet Laboratory are described in this paper. These initiatives evolved through the efforts of the ECET Department at Queensborough Community College to introduce computer and Internet-based strategies into the learning and teaching processes. This effort was funded in part by National Science Foundation (Division of Undergraduate Education - Advanced Technological Education).

Initial Efforts for An Integrated Interactive Web-based Laboratory at QCC

An Interactive Internet Laboratory is presently used in electronics laboratory courses given by the Department of Electrical and Computer Engineering Technology at Queensborough Community College. On-line experiments and support courseware may be seen and downloaded at www.mission-technology.com.

The essential components of this version of the IIL system are:

- Computer controlled bench-top instruments (Hewlett Packard) consisting of a digital multimeter, oscilloscope, signal generator and power supply;
- Interactive Web-based lab experiments;
- Web-based instrument controls;
- Subject tutorials;
- A custom Web browser (WebLAB) that tightly integrates all of the above hardware and software.

With NSF support, 6 sets of computer-controlled bench-top instruments at $6,500 per setup were installed as shown below.
Real laboratory instruments may be controlled through a PC using an integrated computer control panel or manually. Using the WebLAB browser students have on-line access to pertinent instrumentation and interactive subject tutorials. There is a Web page for each part of a multi-part experiment -- students must progress through each Web page -- containing multimedia laboratory materials – to a subsequent Web page only by correctly answering verbal and computational questions.

Unlike traditional lab assignments presented in a manual or paper handouts, students only see a single Web page with a single segment of each experiment. In order to advance to the next part of an experiment, a student must, not only have assembled all experimental data, but must also demonstrate comprehension and data correctness by answering key questions interactively on the Web page.
A New Approach - The Remote Interactive Internet Laboratory (RIIL)

The new era of Web-based scientific education holds great promise for customized asynchronous delivery of meaningful laboratory instruction over the Web. In the remote version of IIL students can have real laboratory experiences with all associated resources available on the Internet.

The other three most familiar educational strategies have substantial drawbacks. The traditional method requires students to perform mandated laboratory assignments in campus laboratories. Traditional laboratory instruments and facilities require costly startup, maintenance and setup costs. Another approach allows remote users to control instruments connected to a host instrument-server. This is effective when the laboratory instruments are too costly for institutions to install. A major deficiency of this approach is that each experiment must be performed online as the “experiment of the week”. To make all course experiments available is extremely costly. A third approach compromises the promises of technology by substituting computer simulations of real instruments and measurements. This virtual method deprives students of experiencing and observing real physical phenomena in their course of study.

The Remote Interactive Internet Laboratory

The hardware component is a proprietary data acquisition device called e-LAB and the software component, integrating e-LAB hardware with a PC and the Internet, is called WebLAB.

The synergistic union of WebLAB software and e-LAB hardware opens up new opportunities for introducing and improving science and technology education at all levels of education in a cost and space effective manner.

In the RIIL, an e-LAB device replaces all of the complex instrumentation present in the traditional laboratory. Within e-LAB, a complete set of instrumentation is contained in a low cost, single small lightweight rugged box, with the following capabilities:

- A dual channel oscilloscope
- Digital voltmeter
- Triple programmable power supply
- Sine square generator
- Spectrum analyzer
- Strip chart recorder
- Frequency counter
RIIL System Components

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<th>HARDWARE COMPONENT</th>
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5” x 4.25” x 1.5”

Close-up of interactive Web based laboratory exercises with real instrument control panel to acquire and process real data.

Objectives for the First Trial for Real Distance Electronics Lab

For ease of universal access and fast updates, Microsoft’s Internet Explorer Browser provided the environment for complete lab delivery. To achieve WebLAB’s total integration concept, Microsoft’s ActiveX technology is used to control the instrument and deliver the related interactive tutorials. WebLAB materials as well as information on e-LAB may be found at http://www.mission-technology.com.

The development activities leading up to this trial included four years of designing, building and improving the instrument over three models to make real distant laboratories possible. While the objectives of this first trial are modest, it is hoped that this first step paves the way for others to extend the trials with greater quantitative assessments in more suitable and rigorous educational environments.
More detailed quantitative assessments, for this project, were not warranted since until recently our college did not support distance education. At this time our college is implementing campus-wide distance-learning strategies. This project was the next logical step to our online lab research initiative within the ECET department. We performed the trial with volunteers from a regular lab class comprised of students, not pre-selected in any way, whose average HS entrance grade hovers near C. Our cohort was typical for an urban community college where many are poorly prepared for college work, lack good study skills, and are poorly motivated. Indeed, we do have some students who are well prepared and highly motivated. In this environment, our hope is to provide answers to the following questions:

1. Will students be able to successfully carry out all parts of a lab experiment at home using e-LAB, Internet based instrument operating panels, online experiments and tutorials?
2. Will the instrument hold up to months of unsupervised student use and rough knapsack transport?
3. Can the e-LAB instrument carry out all the experiments designed for the Hewlett Packard suite of instruments used in the IIL system described above?
4. What are the possible benefits from this approach for the student when compared to traditional laboratories?
5. What other problems and drawbacks will be observed?

Summary of Distance Lab Trial Methodology

- In a lab class with nineteen students working in 6 squads, the first two laboratory sessions were carried out in class using the e-LAB instrument. This approach made all the students familiar and comfortable with using the RIIL system.
- At the end of the third lab session, those squads whose members had computers and Internet access were given an e-LAB, with wires and components, in order to do the following week’s experiment at home.
- Success was measured by the students’ ability to submit competed lab reports with correctly captured signal waveform results and processed data before the start of the

**Interactive Web-Based Lab Setup**
next regular session. Those who were unsuccessful at working independently had an opportunity to do the lab traditionally with other students at the next lab session.

- Communications with the students were carried out mostly by email. Phone calls were used in one instance when email was not successful. Meetings during the week also took place whenever necessary to help solve problems.

To insure that outside collaboration did not result in merely copying results, frequent quizzes, dealing with both practical and theoretical aspects of the experiments, were given in class every 3 weeks.

Outcomes Summary

- Out of three squads that originally tried the remote lab approach, 5 students or about one quarter emerged with the ability to do the labs successfully at home. With six instruments on hand, each participating student had a complete lab setup with e-LAB.
- The lab assignments for the students with the instrument at home were made asynchronous, meaning they could progress faster than the weekly lab schedule. Two more talented students decided to move ahead of others enrolled in class. This increased independence motivated these two students to purchase their own breadboards and parts to experiment on their own.
- As a consequence of students working at home, the regular in-class size was reduced. This allowed students to work in smaller squads and profit from more hands-on connection with the apparatus. It must be said this hybrid approach did require more instructional effort. In addition to the extra time spent with the distance students, the extra in class setups of weaker students required more troubleshooting by the instructor.

Project Conclusions

Referring back to the original 5 evaluation questions, the following were derived from the results of the distance-learning project:

1. Students who were prepared and motivated did successfully carry out all the laboratory experiments at home using the setup provided and described above.
2. The e-LAB instrument, designed to withstand ordinary misconnections and abuse, survived three months of student use and transport for this project. To date, after two years of class use all 6 instruments are in good working order.
3. Most experiments originally designed for HP set of instruments were carried out unmodified. Some experiments requiring Op Amps to operate on 12 volts supplies were modified to operate at 8 volts. This was necessitated by the 8-volt limitation of the e-LAB instrument. One experiment requiring a triangular waveform was altered to allow the use of a sine wave in its place.
4. The well-prepared students loved the trial because it saved them time and empowered them to carry out their own pet electronic projects in addition to the regular set of lab experiments.
5. Most of the students, as anticipated, were unable to do their experiments at home since these students are not used to working on their own. Because our college has no dorms and students must travel from many parts of New York, collaboration was impossible to extremely difficult for many. More online capability and support as well as better and more rigorous earlier preparation are necessary before the general population of students can be served at our college by distance-education.

Apart from the greater accomplishment that real remote Web-based laboratories were run successfully, both advanced and regular groups of students benefited in this first trial at the community college level. The better students gained by being able to carry out experiments outside the confines of the classroom. They demonstrated greater interest in the subject matter. The remaining students acquired increased experience with lab facilities in a smaller class setting.

Moreover, more students wanted to participate in the remote lab trial than expected on the basis of their skill levels. There was increased interest in the possibility of being able to do labs at home. Had students been told earlier that they could do remote lab if they progressed effectively in the course, they would have worked even harder in the prerequisite course to qualify for independent work in the current course.

The possibility of our students not getting adequate exposure to other real-life instruments was never an issue since the trial involved only one lab course out of a dozen that our students are required to take. Even if e-LAB was used in most of the labs, exposure to common real-life instruments can still be easily accomplished since students can experience these instruments in advanced lab sessions. Another solution is to design the control panels used by the e-LAB to exactly mimic popular mechanically controlled instruments. Migration would then simply replace mouse-controlled actions with fingered mechanical operations.

The trial accomplished its modest goals in establishing the possibility and feasibility of real distance laboratories for electronics instruction. For colleges with established distance education experience and support mechanisms in place, the results of this trial might be helpful to them in replacing simulations and going the distance with real electronics lab instruction.

Also from the results of this trial experience we can infer that an immediate beneficiary of this mode of lab instruction could be at four-year dorm-based engineering schools. Students at such schools can easily collaborate and do basic lab experiments in their dorms. This would free up their in class lab time to explore larger more meaningful projects not possible before because of time or preparation constraints imposed by the need to do basic experiments there. Such students will also feel empowered to try experimentation on their own and further inspire their creative skills.

The Future for e-LAB and Online Lab Instruction

There is a call, nationally, to stimulate interest for studies and careers in science and technology by introducing important technologies earlier in the educational process. Distance learning
systems have mostly facilitated delivery of course content information and laboratory demonstrations. While much progress has been made in the delivery of classroom materials, either over networks or other audio/video means, there are major issues that need to be addressed in order to provide meaningful hands-on laboratory experiences in science and technology courses, namely:

- Science and technology laboratory facilities are costly;
- There is a short supply of qualified science and technology teachers;
- School authorities are adopting and requiring performance standards.

Future development of e-LAB and turnkey WebLAB systems can solve these problems by providing:

- A low cost solution for science and technology laboratory experimentation and demonstrations.
- Teacher education and training on instructional system.
- Integration of science performance standards into the design and implementation of science experiments and demonstrations.

Since e-LAB's multipurpose instrumentation is computer controlled, it has even many advantages for use at the K-14 level. The instrument is controlled in large part by a mouse, which means that many young student-experimenters will begin in familiar territory. Also since the instrument’s appearance and function is controlled from software, it may be introduced with very simple picture-based controlled functions.

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