Online e-learning Environment for Delivering Real Hands On Laboratory Experiments

Nathan Chao, Queenborough Community College CUNY

Introduction

Internet technology and web-based approaches to engineering and technology education have made great instructional inroads both for students and faculty. Apart from the millions of students already receiving educational material over their schools' intranets, nearly a million students were enrolled in distance learning courses last year according to a research report from International Data Corporation. IDC projects that 3 million students will be enrolled in such courses in three years.

Students are now learning with extended and alternative cognitive skills and faculty are changing traditional collegiate instruction for web-mediated approaches. Engineering content and materials are being put on the Web at an increasing rate.

Much progress has been made in the delivery of recitation type material either over the net or by other audio and video means. For example, in a generous gesture, MIT plans to put all of its courses on the internet. This 100 million dollar undertaking will make MIT caliber course materials available for free to anyone in the world. By doing so, MIT is certain that it will raise the standard of science and technology education all over the world. Schools in poor countries will be able to gain easy access to world-class material prepared by world-class educators.

In science and engineering education, laboratory courses with real hardware and test experiences are mandated curriculum requirements. A student's exposure to real hands on apparatus fosters the process of discovery and independent thinking that is the basis of this country's success as the most innovative nation in the world. However there are still major obstacles to web delivery of meaningful hands on experiences for science, technology, and engineering laboratory courses.

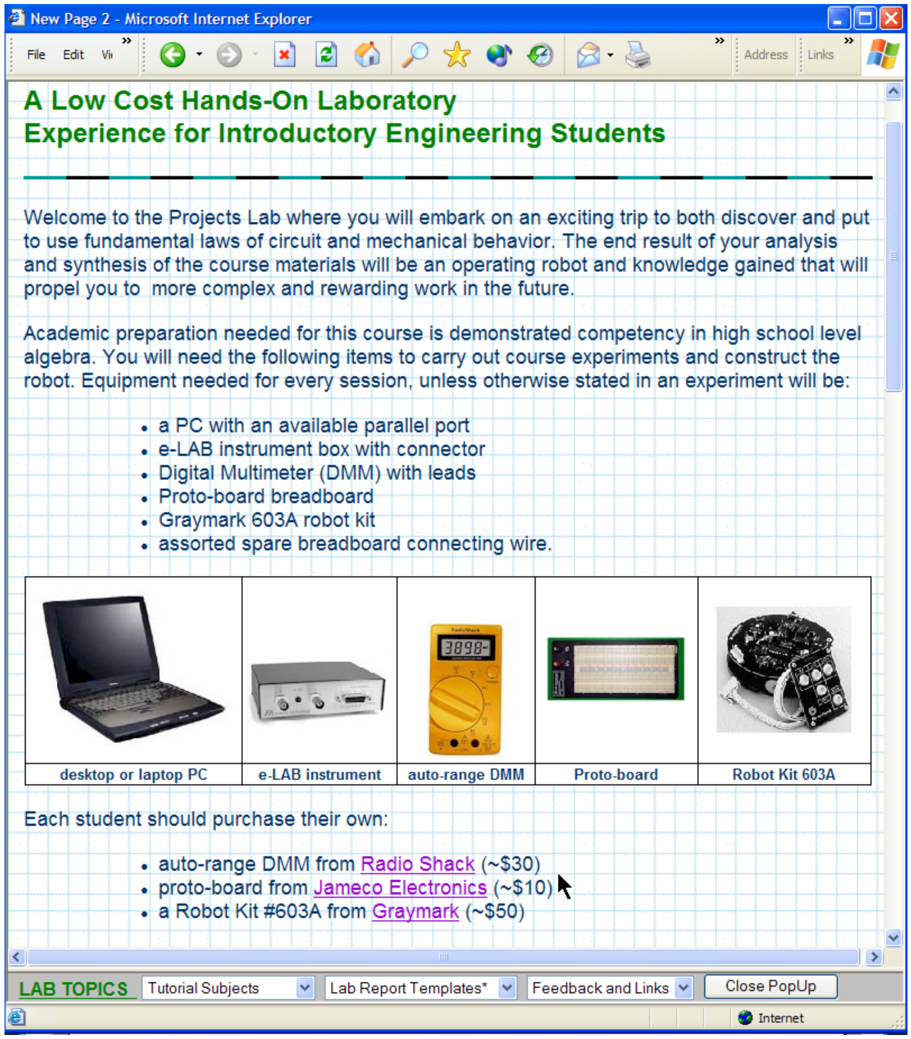
The three most widely used educational strategies for delivering laboratory experiences all have substantial drawbacks.

1. The traditional method requires students to perform mandated laboratory assignments in campus laboratories, where traditional laboratory instruments and facilities require costly startup, maintenance and setup costs.
2. Another approach allows remote users to control instruments connected to a host instrument-server. A major deficiency of this remote approach is that it deprives students of hands-on wiring or setting up their own experiments. Also, with this approach, each experiment must be performed online as the *experiment of the week* since it is extremely costly to make all course experiments available simultaneously.
3. 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.

New Lab Delivery Paradigm

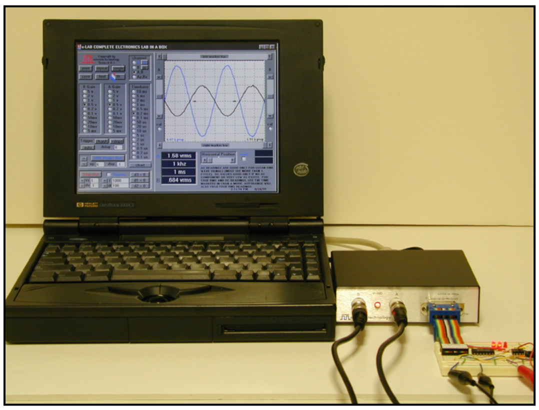
Using new hardware and software technologies, an affordable interactive multimedia e-learning environment for delivering real hands on laboratory experiments was developed that is vastly superior to traditional paper based delivery and the other primitive web based approaches cited above. The totally self contained asynchronous modules of this new approach can be used in a school laboratory or at home by the student in a distance learning situation. The cost of this total e-learning lab environment is only a small fraction of the cost of traditional hands on laboratory environments. The low cost makes this revolutionary approach an effective solution for distance labs in this country and for global delivery of valuable hands on lab experiences for poorer nations.

Students will be learning in an enriched environment integrating web-mediated learning technologies with cognitive advantages of the hands on laboratory experience. Instructional modules integrate seamlessly subject material, tutorials, structured online questions and feedback, calculations and verification of theory, graphing tools, laboratory preparation templates with questions that require independent and collaborative feedback, and integrated assessment tools for evaluating module effectiveness. The cycle of continuous improvement built into the structure of this e-learning environment anticipates ABET's latest requirements.
A successful proof-of-concept project, a web-based, hands-on course designed for freshman engineers at VCU (Virginia Commonwealth University) was conducted this year. Students are led through the construction of a robot including 12 experiments that teach all necessary electrical technology fundamentals in order to understand how a robot systemically operates. This completed e-learning environment may be viewed on the Queensborough Community College World Wide Web server at the following URL: http://web.acc.qcc.cuny.edu/nsfrobot/ .

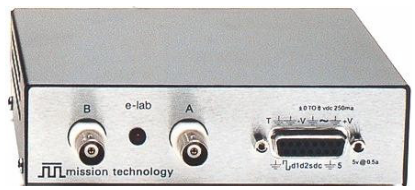


The main hardware component integrated into the e-learning lab web based environment is an instrument designed specifically for student use. This instrument called e-LAB is a low cost, space saving, student proof, easy to use replacement for traditional bulky, expensive and costly to maintain instrument suite consisting of oscilloscope, power supply and signal generator. This instrument has proven itself in use at many schools throughout the country over the past 6 years. Custom instrument control panels for each experiment are as simple to use as possible for the experiment tasks at hand and are embedded into the online laboratory exposition. The synergistic union of e-LAB and custom embedded ActiveX instrument controls tailored for the educational level and content of each lab module of the integrated e-learning environment opens up new opportunities for introducing and improving science and technology education at all levels of education in a cost and space effective manner.

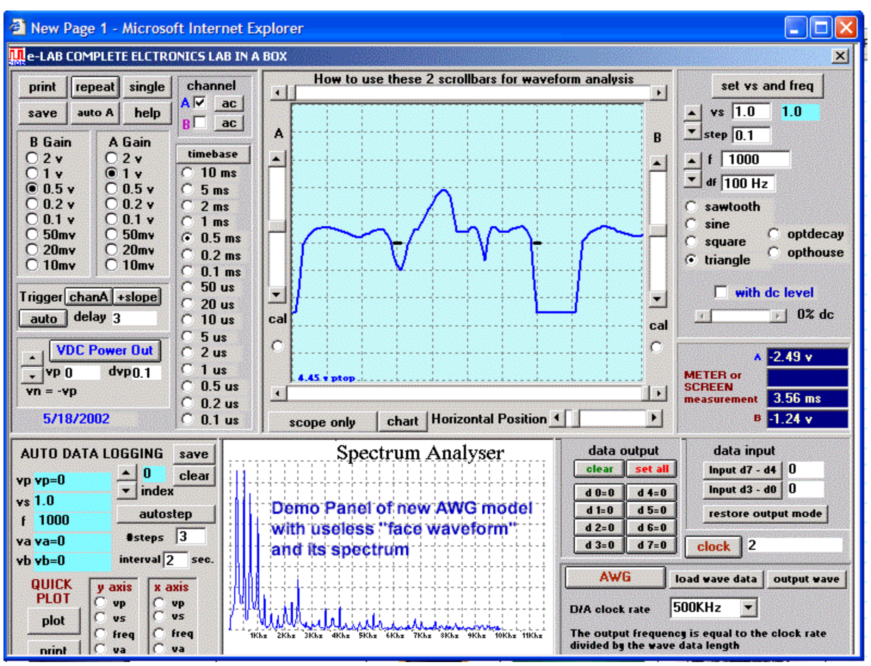
The instrument, e-LAB, is shown here controlled through an instrument panel contained within a custom browser. It is to be noted that this experiment setup is real and is in no way *virtual*.
Waveforms shown are obtained from wired negative gain op amp.



e-LAB Instrument
A real computer controlled instrument with a built in dual channel oscilloscope, chart recorder, triple user dc power supply and sine, square signal generator



Full Instrument Control Panel



This full instrument panel controls all e-LAB functions:

- dual channel - digital storage oscilloscope
- strip chart recorder
- dual digital voltmeter
- digital frequency meter
- waveform segment analyzer
- continuous spectrum analyzer
- triple user dc power supplies
- square wave gen.
- AWG function gen.
- 8 bit I/O

e-LAB replaces many pieces of costly and often fragile equipment while requiring minimal space.

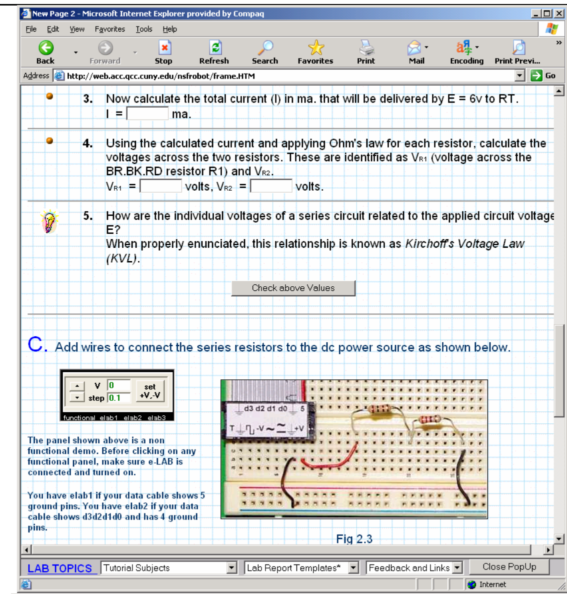
e-LAB's use is not intended to supplant the use of modern conventional instruments. The use of e-LAB technology, combined with a low cost DVM ($20-$30), is appropriate for many lower level engineering courses. By fully integrating Web-based courseware with the instrumentation process, new students are more able to discover engineering principles quickly and in turn appreciate the relevancy of their studies. In subsequent courses it is fully expected that students will be able to better deal with instrumentation complexities. Having good measuring experiences and the commensurate confidence will only make the transition to other instruments easier and less intimidating

Hands-on e-Learning Lab Environment Description

A fully developed set of laboratory experiments designed with all the elements described below has been fully student tested during summer 2002. The results of that testing posted at http://www.engineering.vcu.edu/fac/tait/egr101/index.html has been used to refine the online materials. This refined set is being used this (fall 2002) semester at the Virginia Commonwealth University for their introduction to engineering laboratory course by a small number of students limited by the number of e-LAB instruments allocated in the proof of concept project.

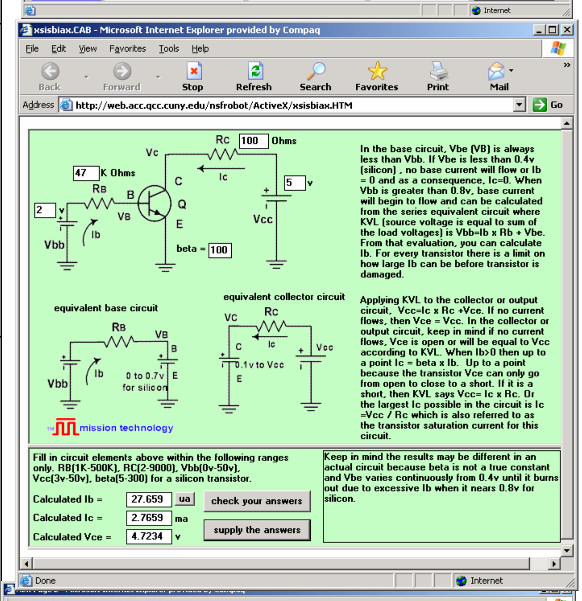
The totally integrated web based e-learning environment consists of the following components for each laboratory experiment.

Interactive lab content which asks students questions and evaluates their answers and data before allowing them to progress are included on each lab web page. This embedded interactivity ensure individual student learning whether in a large class setting or in solo distance learning situation.



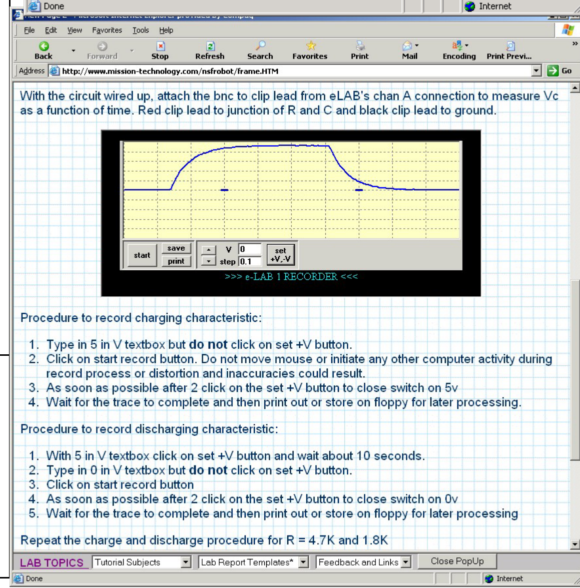
Vivid color photographs, audio and video clips are included in many lab web pages to make experiments clearer and more interesting.

Custom tutorials tailored to answer common questions and address typical problems student have are provided for each lab exercise.
An example is shown at right,



Custom web page embedded instrument panels are provided for each experiment to make instrument use easy and natural as the student progresses in ability to handle more complex instrumentation.

An actual (real, physical and NOT simulated) charge/discharge capture by the web embedded instrument panel is shown at right.



Lab templates and graphing aids to assist students in preparing well organized and useful laboratory reports are there if needed.

Advantages of Web-based Lab Presentation

- Student responses made on the Web page to questions posed there are instantly evaluated, allowing them to progress with confidence. In this way individual student learning can be verified, even in a large class setting. It is our experience that in large laboratory classes many laboratory squads mechanically progress through a traditional printed laboratory manual. By merely following instructions and collecting data, many students do not bother to understand fully or to verify the correctness of data. A Web-based laboratory manual ensures that every squad correctly understands each part before they progress to the next part of the experiment. If they fail repeatedly to progress (navigation block on error), the instructor will be alerted that the students need assistance.
- The Web can provide unlimited resources of supportive materials that allow students to get answers to almost any question they may have concerning a laboratory topic.
- Colorful supporting graphics and multimedia materials makes the laboratory topics and procedures both easier to understand and more attractive to use.
- Collaboration and participation are fostered on the Web since the students may easily communicate with each other or even anonymously with the instructor to share viewpoints concerning the lab.
- Built-in graphing aids and laboratory report templates can alleviate the tedium and confusion in creating a good readable report.
- A Web-based approach also permits timely corrections, expansion of module content, and the ability to incorporate good suggestions quickly based upon evaluations and feedback.

Feedback Summary

Provided by VCU Fall 02 beta class

“Strengths:

1. Photographs are quite helpful in wiring up circuits correctly on the protoboard and assembling the motor gear system. The use of ‘real-time’ diagrams and pictures on the web is a distinct advantage over the manual. The section on motor operation is very good.
2. Tutorials can be a good reinforcement of material learned in class (provided material has been covered in class – see # 4 weakness below). The dynamic tutorial (Lab #8) and SRAM tutorial (Lab #9) were particularly beneficial. Visual aids such as these were highly recommended by students as models for more such tutorials. Also, on-line quizzes are a great way to check your progress through the lab.
3. Links to other sources of information on-line are valuable, and students avail themselves of this feature.
4. Laptop control of eLab box is easy and versatile – it would be good if we had full panel control in addition to just the active-x windows in the laboratory web pages. The technology impact of the eLab devices was very highly regarded by students – these boxes are “a hit” .
5. The use of a lab template provides essential guidance to putting together a meaningful report, and is a good learning tool. Quality of lab reports are superior to those currently submitted by freshman students in the course. The students appreciate the ‘professional’ look of the templates.
6. The ability to work at one’s own pace improves understanding of the material, and is an advantage over the fixed, three-hour sessions in the regular lab section.
7. Students have a sense of gaining experience with cutting-edge technology, and find it ‘extraordinary’ to watch their laboratory circuit being controlled inside a laptop browser.
8. The approach fosters teamwork, as students need to check method and results with others in the absence of TAs or the instructor.”

Weaknesses Summary

There are many weaknesses noted for each experiment module in this first class trial. The most prevalent has to do with the excessive time required to complete some experiments. There are also many content and operational issues. In a robot project lab, it is difficult trying to achieve a balance of testing circuits on a breadboard in a logical topical fashion and construction progress with attendant loss of breadboard components, and troubleshooting soldered in non working circuits.

There are also issues of the lack of clarity in some difficult topic presentations and the need for more tutorials dealing with those topics.

The major thrust of the weaknesses feedback is that, with the modules in their current state, most students do not feel they can perform all the experiments without faculty assistance.

Feedback Response

For any new course, original pace estimations always need to be readjusted and sometimes drastically to reflect the true average student progress speed. This can only be ascertained through the natural feedback process after the home or classroom trial. Similarly, only through feedback which may take several rounds of improvements spanning different groups of students can modules eventually be perfected to satisfy one of the goals of requiring minimal faculty assistance.

It is amazing in all the feedback, the e-LAB instrument was not faulted in its seamless role of providing real physical voltages, signals and measurements in each experiment module. The only complaint was that a general purpose instrument panel was not provided to make troubleshooting none working soldered in circuits easier. In most regular breadboard only labs, that would not be an issue.

Conclusion

From the feedback, it is clear that the e-learning environment as constructed and described in this paper can work and provide a viable alternative to other methods currently used to deliver laboratory experiences. From the point of view of cost and the ability to offer distance lab opportunities, the e-learning environment with e-LAB represents a new paradigm for global delivery of meaningful real hands on laboratory experiences for students of science and technology.

Need/Impact (excerpted from VCU support narrative by Dr. Gregory Tait)

"It is well documented that from the time new engineering students take their first courses, many never reach their goal of completing the degree. Nationally, engineering majors suffer one of the highest attrition rates compared to majors in other subjects. The cause most cited is the lack of connection between traditional broad-based first-year engineering courses and later engineering course experiences. Many students gravitate to engineering because of the excitement of all the technology products they see and use. However, when students start taking the first round of courses in their newly chosen field, they often encounter difficult courses that appear remote to the exciting applications that drew them initially to choose engineering.

Based on initiatives at Carnegie Mellon in 1995 intended to redesign and implement a new engineering experience, many engineering schools have restructured their curricula. VCU School of Engineering has addressed retention issues by adopting freshman experience courses that are student-centered and project-based, integrating theory with hands-on projects. This approach recognizes that today's technology is based upon complex systems and that it takes too many sequentially related courses to acquire sufficient knowledge to understand these systems.

The significance of this proposed project lies in the potential to provide a large number of entering engineering students with meaningful and exciting laboratory experiences using modern teaching tools. Current ENGR 101 laboratory sessions are crowded and hectic, and many students feel frustrated and neglected. The educational objectives are too often not achieved, leaving students unprepared to continue in higher level courses. Engineering students are naturally energized to be on the cutting-edge of new technology, and will be excited by the new approach proposed here.

The use of remote instrumentation to provide a hands-on laboratory experience for students will have a far-reaching effect on the way engineering faculty can offer their discipline-specific laboratory courses. The ENGR 101 service course alone directly affects all engineering students and involves several faculty members in the electrical, mechanical, chemical, and biomedical engineering programs. The follow-on course, EGRE 206 Electric Circuits, is a sophomore-level service course for electrical, mechanical, and biomedical students that would similarly benefit from a capability to offer remote laboratories. The ability to use computer-controlled test instruments and modern data acquisition techniques will continue to be a primary learning outcome for students in the School of Engineering.

An additional consideration concerns transfer students (into the VCU School of Engineering). Presently, associate degree students are entering the program without the same laboratory skills and experience that our freshman and sophomores acquire. Traditional in-class laboratories require test instruments and facilities that are very costly in startup, maintenance, and weekly setup. A suite of test instruments for one student station in the laboratory costs approximately $6000. In contrast, a laptop computer and e-LAB instrument device cost approximately $1500. Community colleges and engineering students themselves can afford* this powerful test setup. Coupled with the on-line laboratory materials available, this approach will have a major impact on teaching these students."

*Currently produced in low quantities, e-LAB costs $399 each in purchases of 10 or more. With growing demand and larger production, it is anticipated that the cost of each instrument can drop below $300.