Electronic Laboratory on the Internet

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Abstract
The focus of this paper will be on the usage of an electronics laboratory on the Internet as an alternative or in addition to a physical hardware electronics lab. Software simulators, logistics, cost, security, the Internet, the World Wide Web, and usefulness of the marriage will be discussed.

Introduction

Research was started to discover what support could be given to a sophomore level basic electronics AC/DC class by using remote resources. Some students need more laboratory time to understand concepts. Some students need laboratory time because they have made mistakes on the first attempts. Some students are not able to handle the physical laboratory because of a disability but they can operate a computer.

The initial need for an alternative laboratory came from a student that wanted more laboratory time but didn't have campus time to spend there. The student commuted and was going to school to enhance their job skills and not for a total change in job type or function. The requirement was to find a way to work on a laboratory assignment from their home when the physical laboratory was closed.

Distance learning is the process of bringing the classroom to the student. Chemistry classes have been taught using video tapes and chemicals sent to homes. It is possible but expensive to send a well equipped electronic laboratory to an individual home. This would require a multi-meter, AC-DC signal sources, an oscilloscope, a prototype board, and RLC discrete components. It is possible that given a very good video tape walk-through on all of the equipment and each of the laboratory exercises, the student could learn something and that the equipment might survive. Should this plan be approached, considering the cost, the potential to teach electronics is marginal. The opportunity to make mistakes in the presence of someone who can assist in the recovery from those mistakes is a necessary element of the hands-on-laboratory. A laboratory without the possibility of mistakes is worthless. The detailed video that could allow operation of a new piece of equipment would not solve the need for some method of recovery from errors in connections, operation, or theory. This would cause extreme frustration on the part of the student. A physical laboratory with all of the hardware and an instructor would seem to be the best choice. As an alternative, an electronic simulation of the laboratory and a method of communicating with an instructor is being explored.

The Internet is being used as the communication link to an instructor. Electronic Workbench and Current Maker are being used as the laboratory simulation. Students may use the simulators while in or out of the physical laboratory. Disabled students need the simulator in the lab.

Students working in the laboratory after regular hours can find assistance via an Internet link.

Laboratory

Electronics classes typically require a lecture and laboratory. It has been recognized that lectures are not necessarily the best way to transmit knowledge[(1)]. Hands-on education in an applied technology program will require participation in a hardware laboratory. If we view the laboratory as a place to make mistakes, see new situations, realize / prove theory, "touch" the problem, or visualize the associated mathematics, we see the lab as a hands-on lecture. The objective in my basic electronics laboratory is to teach the use of equipment so that descriptive parameters of electronic events can be recorded. Lecture time is used to describe parameters and teach the techniques of calculations. Laboratory time is used to measure these parameters and show that the calculations and measurements correlate.

Typically the laboratory is supervised by someone who can answer questions or assist in the recovery from mistakes. The laboratory tends to be a walking lecture for the professor and could be improved if everyone could hear and see what each student asks as a personal clarification question. Since the student is engrossed in his team's work, questions from other students are often lost in background noise. Each laboratory team may need instruction on instrument operation and in circuit theory. When questions from students repeat, we try to address the answer to all students. This is usually only partially successful because of the distractions in the lab and the fact that students are thinking of other problems at the moment. Grouping the questions and answers on an overhead projector may be a method of passing the information to others.

Simulators

One of the methods used to assist students in laboratory error recovery are electronic simulators. These provide a method by which the student can verify answers and discover where the error was made. Two of the packages, which I have used, tend to focus in different directions. Electronic Workbench[(2)] is designed to be a computerized workbench simulation. It contains "components" in racks, has "equipment," and requires "cable" connections to read the parameters of a circuit. Current Maker[(3)] is an electronics problem generator with a circuit solutions calculator.

Electronic Workbench acts like a work bench[(4)] and requires the user to build the circuit on a graphics display and then make connections to the proper piece of equipment to measure parameters. Current Maker acts like a graphics calculator and requires that the user draw the circuit so that node voltages and currents can be computed. Voltage and current are automatically calculated and displayed as polar complex numbers. Electronic Workbench would show a node voltage but require the user to use the dual trace scope to find a phase angle. Current Maker displays parameters as calculated in typical homework problems. Electronic Workbench displays parameters as shown on laboratory equipment.

Comparison of the answers is still a problem for the student. The homework, simulators, and equipment in the laboratory all display answers in a different format. An ability to write the

parameter displayed on an oscilloscope as a mathematical term consistent with a homework circuit problem solution is a course objective. Communication requires that a representative number is found for each parameter of a circuit. Both of these simulators are valuable in the calculations / laboratory / parameters education processes.

Some laboratories require a simulator as part of the hardware[5]. I have required a Current Maker solution for some historically difficult laboratory problem circuits. The student still needs to interpret what the equipment says versus the node voltages computed by the simulator. The ability to interpret what is measured is part of the learning that must take place. Another instructor[6] requires his students to setup Electronic Workbench before they do the hardware circuit. The students easily configure Electronic Workbench but have trouble with the hardware circuit. This would suggest that the "work bench" physical world is not duplicated in Electronic Workbench. Electronic Workbench is a much more controlled environment than the average physical work bench. It is a good simulator but the laboratory problem and its visualization is easier to see in Electronic Workbench than in the real world. Possibly this is because the graphics display allows the user to control the computer simulation better than the wires on the real bench. Visualization of the physical hardware connections may be part of the mental electronic structures problem.

The Internet / World Wide Web

While the Internet is a fantastic idea, it is not the solution to all problems. Created in the 1960's as a way to distribute and preserve information in the event of a nuclear attack[7], the Internet is only a distributed file system[8]. It is not noticeably different from a peer-to-peer network in function. Of course the Internet does have the ability to pass data without regard to the computer's operating system which means computer type is not a limit to communications. The system was made for file storage and not computer operations. The World Wide Web (www) has added a browser interface to the Internet. This allows anyone to place a "page" of information on a networked computer that can be accessed as a "page" of text and graphics. The computer with the "page" on the network is only holding the "page" and is not running an accessible program. Communications are taking place to pass the "page" of information as requested by a linked computer. Thousands of computers have been linked by being present on the same network. The network requires that each computer has an address like a phone number. In this way each computer knows where to send the packets of information that are requested.

When a user wants to read what is on the "web," they must have a computer that can gain access to the Internet. This could mean a home computer that has a telephone modem link to a network provider [This would cost about $20/month to the provider. The telephone modem is a one time cost of $100.] or a school computer that is tied to the school's network lines. [This usually cost the department a flat fee.] The user would start a program similar to Netscape which can be downloaded from the web or is part of the provider's package. Netscape is a web browser whose function is to communicate with any computer specified. If you put an address in the box at the top of the web browser, the information located at that address will show on your computer.

No programs but the web browser and the networking program need to be running and you as the

user have control of only your machine. The computer providing the "page" of information looks like a file on your hard drive. You cannot operate the other computer's CPU from your location with the web browser. If you have access, you could change the "page" on the other computer but you cannot control the other computer's processor chip. The other computer may have programs operating that can collect data from your computer. How much information the other computer can get from you is in question.

Operations

The simulator must be run from the user's computer. Data can be stored on another computer but operating a program on another computer requires that the program be written for network access. Netscape will not operate the simulator on another computer. Our university Internet pages are stored on a VAX. The simulators do not run on the VAX but could be distributed as a file from the VAX. If Electronic Workbench was running on the same computer that had a web server running, you could view the "pages" that were saved at the web address but could not see or control the simulator. If the web server contained figures from a laboratory manual and the student was to use the figures as a reference point to operate their own simulator, all students could view the same page at the same time.

If a robot controlled hardware system was used instead of a simulator, only one person at a time could use the system. The physical laboratory cost and control would include video, electronic hardware, computer, Internet access, and a robot. This would be departmental cost and create a bottleneck in student usage time. This type of control has been used but seems too restrictive as a hardware laboratory alternative. Special software would be required as Netscape cannot do this.

Laboratory on the Internet

Electronic Workbench and Current Maker are both copyrighted programs and their owners have no interest in distributing them free of charge on the World Wide Web. This means that the user must provide his own copy of the simulator and not expect to download it from the classroom page. A link could be provided to the simulator company where the program could be purchased and downloaded. Currently student copies of Electronic Workbench are available only from a university book store. Electronic Workbench for students cost $150 and Current Maker cost $15. Current Maker is not attempting to simulate the laboratory experience. It is used as a circuit solution calculator and is limited in the complexities that can be handled.

Providing course material on a web site is the same as handing out the material in class. Putting the laboratory experiment circuits on the web is no different from taking the lab book home. Using the web site to collect answers or circuits is the same as filling out the workbook. True, the system could save paper. Our goal is not to save paper but to provide a laboratory experience. Everything that can be done on the web is already being done without the web except for one thing. The web provides a method of communication[9] from the student to someone who can assist in laboratory error recovery. The use of a news group in connection with the laboratory can be valuable. A news group ties question and response together in a chain. A chat room allows all data to flow in time order. For proper instruction, the question and answer must

be tied regardless of the time that it was put on the net. Putting the laboratory on the web requires that the web server provide a news group account for your students. This is usually done when setting up the classroom web pages.

The laboratory consists of pages on a web server. To do an experiment, the student opens Netscape and goes to the course web page and to the proper laboratory exercise. The page on the web includes minor descriptive data about the lab. Students are still required to fill out the workbook. Figures from the workbook have been copied, marked to identify nodes, and scanned using a document scanner. The scanned image is placed on the web laboratory "page" to be used as a reference when explaining the problem to the instructor. The student and the instructor need a reference point to discuss problems. Node addresses are the only way that a student can describe what he sees and how he is connected.

The student now starts their copy of Electronic Workbench. The student computer will be able to run both the simulator and the web browser at the same time. Screen space is critical so the layout of windows is important. As the student works through the workbook on the simulator, questions can be sent to the instructor via the news group button on the course page.

Naturally, students would like to have an instructor available on the other end of the web on a 24-hour basis. Finding an instructor to be available to answer news group inquiries is a problem. Students find the 2:00 a.m. time convenient for additional study time and get stumped with no one to answer questions. The assistance idea works best if the student knows when someone will be available on the news group. When they get stopped in the late night, they know when to expect an answer to their questions. Some instructor relief can be gained by rewarding students that give correct answers to questions on the web before the instructor responds. This has the potential to be a setup but I haven't found it to be a problem.

The questions sent are themselves instructive. By the time the student can explain what is not working, they frequently have the answer to the question. If the student is required to use both the Electronic Workbench and Current Maker in his description of the problem, errors in schematic calculations are avoided. The instructor then knows both the expected voltage and the displayed value as shown by Electronic Workbench. This then becomes a problem of interpretation of data or connections and not an unsolvable situation.

Laboratory workbooks can be completed using either the electronic or physical lab. The only difference is that the physical lab has restrictions in the components that can be used and seems to be harder to setup. A laboratory final is required in my course. I have not yet determined the difference in abilities shown for those students who have used Electronic Workbench instead of the physical lab for all of their laboratory work. Finding hardware components and adjusting to physical equipment differences will be two major problem areas for the simulated laboratory student.

Conclusions

Using the Internet to provide a known reference point for descriptions of electronic circuits and

requiring that the students purchase both Electronic Workbench and Current Maker, will allow the Internet to be used as a communications path to assistance. The student will gain practice on circuit interpretation and equipment setups plus they will have access to an instructor when things go wrong. I view this as a good addition to the laboratory experience and not a replacement of the hardware lab. Simulators can assist the student who is trying to understand the experiment but they cannot simulate the confusion added by a physical part or connecting that part into a circuit.

There appears to be two sequences that need to be taught. These are the theoretical and the physical. The theoretical side is what is addressed in the classroom and on homework. This is the problem done on the board or on an exam. This could also be the problem circuit that is to be duplicated and studied in the laboratory. The physical sequence is where hardware components are used and parameters are measured to describe the circuit under test. Students have trouble correlating the results of the paper problem and the physical measurements.

Recording the parameters of a circuit as solved on paper, as shown on a circuit simulator, and as measured in a physical laboratory are different problems. The largest gap seems to be the paper to physical lab sequence. The easiest gap is from paper to Current Maker's circuit analyzer. Both of these can be addressed in lecture and the solutions can be shown to match. Electronic Workbench duplicates what is seen in a physical laboratory. The student must configure the equipment and take measurements. Solution values must then be put in the proper form to match what was done in lecture. Electronic Workbench is a good addition to any laboratory. It is, however, a much better aid than replacement.

I have more questions now than when I started. Yes, the Internet is a good place to place a problem set and provide training. No, it is not possible for the physical laboratory to be replaced. Yes, the circuit simulators could be used instead of the physical laboratory. No, the training level would not be the same. Yes, simulators are a reasonable alternative for a physically disabled student that cannot handle physical hardware but can handle a computer. Yes, the Internet classroom would be a good and cost effective, remote access electronic laboratory solution. A fully remote solution would be possible by constructing the lab web pages to include answer boxes so that the student would respond to questions on the web lab page instead of in the workbook. This would require the instructor to write a new lab book because the student would no longer need to purchase a workbook and the figures could not be copied to use as reference.

The Internet "electronic" laboratory is actually another classroom. It will provide good information and may provide more than is possible in the physical laboratory because the students can see and respond to all the questions asked and answered via the news group. In the physical laboratory, the students typically hear only their own questions. Adding the question / answer overhead projector to the physical hardware laboratory may improve that laboratory also.

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