Computer Integrated Experimentation
in Electrical Engineering Education over Distance

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Abstract

The paper presents the implementation of computer integrated experiments in FSU/UMCP collaborative engineering programs from educational perspective. The effectiveness of CIE in actual and virtual classroom environments is compared to other experimentation activities. Advantages and limitations are discussed in terms of equipment availability, infrastructure cost, and contribution to various elements of experimental learning.

I. Introduction

The interest for engineering courses offered over distance has been increasing. Many institutions are currently offering self-paced distance education courses as part of their conventional curriculum, or developing complete degree or outreach programs for distributed education. Advanced communication techniques such as web based online courses and interactive video are implemented to provide learning opportunity to a large audience, spread over a wide geographic area. Another obvious advantage of online courses is asynchronous learning possibility for self-motivated individuals through independent study programs.

The University System of Maryland has recently started collaborative engineering programs on several campuses to extend learning resources available in a large metropolitan university to remote areas. These programs combine the advantages of distance education and conventional classroom activities. Frostburg State University (FSU) has been offering electrical and mechanical engineering programs[1] since fall 1997 in collaboration with University of Maryland College Park (UMCP). Students enrolled in the FSU/UMCP Collaborative Engineering Program take all science, math, general education, and basic engineering courses on campus from resident faculty. Upper level engineering courses are offered from UMCP over distance. The main objective of the Collaborative Engineering Education is to provide students located on a remote campus the opportunity to access advanced engineering courses of a metropolitan university. The developed model is an economical way to extend engineering education possibility to remote areas without loosing experimentation and design activities and student-instructor interactions, which are essential for technical education.

Beside many advantages, distance education has also significant limitations in engineering courses with laboratory applications. Various surveys and observations have shown that engineering and science students gain more thorough understanding of physical concepts if they actively participate in laboratory experiments. In fact, active experimentation is also one of the

most important requirements of ABET 2000 criteria. Consequently, interactivity and hands-on experimentation are two important components that must be considered to ameliorate distance education courses in technical areas.

This paper presents the computer integrated experiments developed at Frostburg State University, to increase the efficiency of lab facilities used for "UMCP/FSU Collaborative Engineering Programs." Computer based experimentation is currently being implemented on the FSU campus to provide a support to the existing lab facilities used for basic electrical engineering courses. The ultimate goal of the project is to develop an online lab facility to enable instructors and students located on different campuses to conduct actual experiments and exchange data in real time. The paper discusses the educational aspects of online experimentation compared to conventional lab activities and virtual labs based on simulations.

II. Learning Styles in Engineering and Science Education

Educational theorists classify different styles for perceiving and processing new information on four quadrants[2,3] as shown in Figure 1. The vertical axis represents the perception and the horizontal axis represents the processing style of different learners. With the inspiration of the publication by Harb et al.[3], the author surveyed learning styles of FSU students at different levels of engineering and physics majors. The shaded area on Figure 1 illustrates the distribution of preferred learning styles, estimated by analyzing the answers of 49 students. Figure 2 shows some other results of the survey.
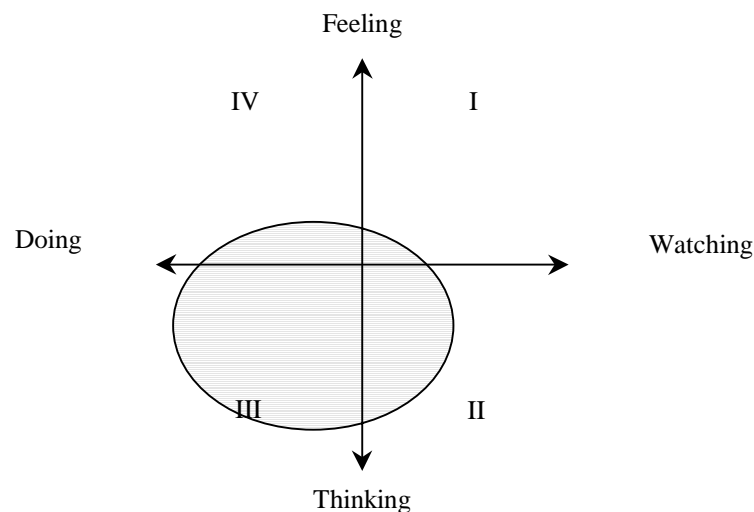

Figure 1   Elements of learning and distribution of preferred learning styles of engineering and science students at FSU (shaded area).

Which one helps you learn better?

Lectures
15%

Reading
assignments
2%

Laboratory
experiments
51%

Homework
exercises
32%

Which one do you like more?

Classroom
discussions
22%

Team work
34%
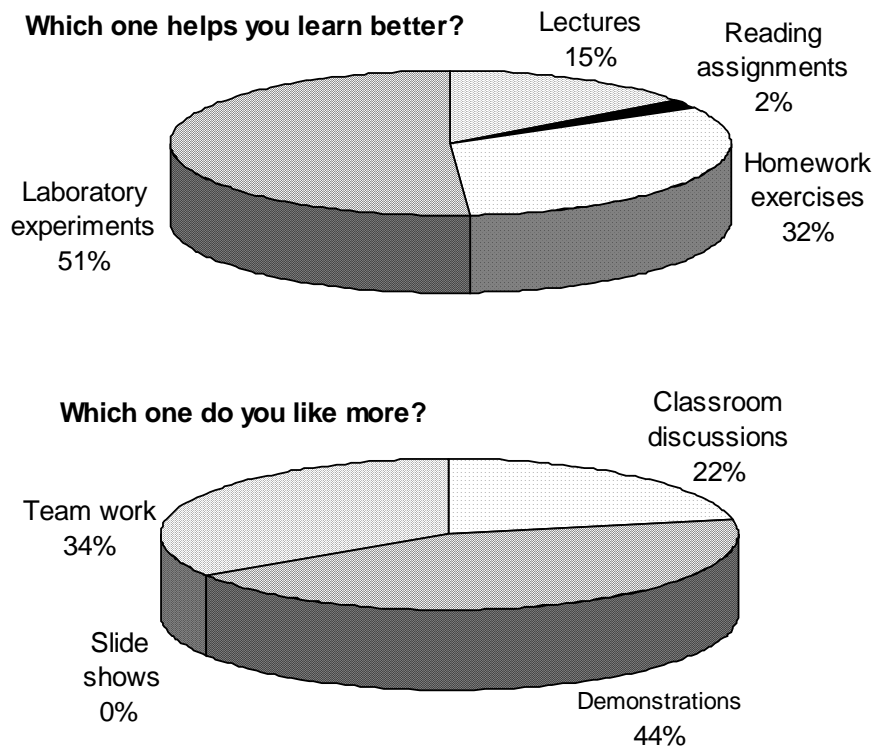
Slide
shows
0%

Demonstrations
44%

Figure 2   Survey results.

The survey clearly shows that the majority of engineering and physics students feel that they learn better by laboratory experiments. They generally prefer classroom activities such as live demonstrations, discussions, and team works to slide-shows, passive lectures, and reading assignments.

Word-processing and computer based presentation tools have significantly changed classical teaching tools. It is now much easier to prepare extensive written documents to hand out, and use colorful and animated slide presentations instead of the conventional blackboard "chalk-and-talk" style teaching. Furthermore, many instructors prepare web based online materials as a support to their courses. It is, however, not obvious that this transformation makes the classroom environment better in technical areas if the active experimentation component is not improved in the same way.

On the other hand, web based teaching has added a new dimension to distributed and asynchronous learning. During last few years, the number of technical courses offered via the

Internet has rapidly increased. A well-designed online course has many advantages over a textbook, due to powerful dynamic visualization techniques. In addition, students have the freedom of browsing the site in the way that fits their learning style the best. Many authors add interactivity to their web courses by using chat and discussion sections, dynamic testing, and feedback. There is no doubt that these techniques can make a virtual classroom environment even more interactive than some conventional classrooms. Nevertheless, an online technical course can not be complete if students do not actively perform experiments and observe physical phenomena.

III. Computer Integrated Experimentation

The term "computer integrated experimentation (CIE)" is used here to express that various elements of an experiment such as equipment control, data collection; information processing and analysis are coordinated in the computer environment. In this context, CIE can be implemented in the following levels:

- Hands-on lab experiments (on-site)
- Access to lab facilities from different locations on campus
- Online experimentation over distance.

The general layout of a CIE facility for on-site experiments is shown in Figure 3. The laboratory equipment and experimental setup are interfaced with the PC through GPIB (General Purpose Interface Board) and data acquisition cards (DAQ). GPIB coordinates the communication between the computer and various test instruments such as oscilloscopes, function generators, multimeters, etc. connected through IEEE 488 protocol. A data acquisition card provides analog-to-digital (A/D) and digital-to-analog (D/A) conversion for data input and output. Most DAQ available at affordable costs have analog inputs to read analog signals, analog outputs to generate analog signals, and number of digital input/outputs to control digital elements and receive digital feedback signals.
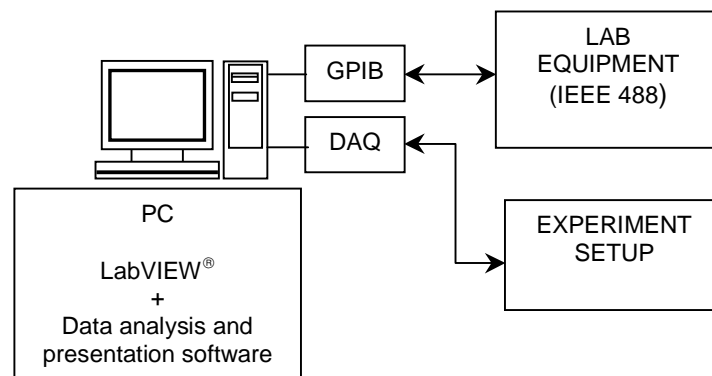

Figure 3   Layout of a computer integrated experiment workstation.

The CIE workstation developed at FSU consists of a PC equipped with one GPIB and one DAQ card. DAQ can perform A/D and D/A conversion at a rate of 100 K samples/s. It has eight analog inputs, two analog outputs, and three eight bit digital I/O ports. Analog inputs can be configured as single ended or differential mode to measure up to 10 V or ±5 V respectively. The LabVIEW® version 5.1 software is used for instrument control, data acquisition, and visualization.

The workstation shown in Figure 3 can be used as a server for online labs, by using "LabVIEW® Internet Toolkit" software. This software provides an http server utility and development tools for CGI, SMTP, and FTP applications. Figure 4 illustrates the general layout of an online lab facility.
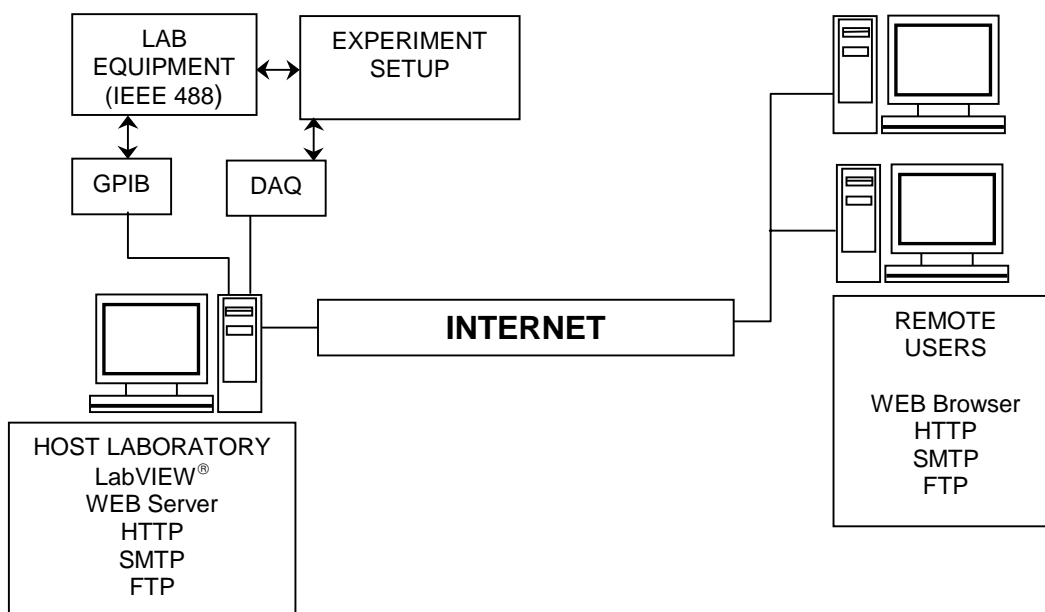

Figure 4   General layout of a computer integrated experimentation facility for online labs

The server can control data transfer with up to fourteen IEEE 488 instruments. At present one digitizing oscilloscope (HP54601A) one function generator (Fluke-Philips PM5138) and one power supply (HP6642A) are hooked up to the server. DAQ is used to perform DC or relatively low frequency measurements directly on the experimental board. Digital outputs are used to control solid state switches or reed relays for changing circuit configurations or element values.

A dedicated virtual instrument (VI) is specially designed for each lab experiment to allow easy manipulation of the physical setup. The front panel of the VI displays measured values, waveforms, and the actual state of the experiment. The VI's can be operated either directly on the server PC, or from a remote computer connected to the Internet. Remote clients can start and stop available VI's to control the physical setup and exchange data by using any WEB browser. No particular software is needed at remote computers. However, some browsers do not support server pushed animations to refresh automatically the VI front panel. For this reason, Netscape

4.0 or a later version is recommended to monitor the actual status of the experiment from an animated VI front panel.

Each VI provides the option of returning all acquired experimental data to the user by E-mail if requested. The server can run several VI's simultaneously. In the case, multiple users access the same VI they can all see the front panel, but the input data is processed on first-come-first-served basis. While a user operates the VI, a "System Busy" message is displayed on the front panel.

Composition of the web page is very important for easy usage and pedagogical effectiveness. The web page must be designed by considering the educational objectives as the first priority. Pictures, video images, and sound transmission are useful to enhance the interactivity. However, experience has shown that unnecessary details and animations may result in longer downloading time (especially in dial up connection) which may distract the user and reduce the educational value of the experiment. In general, filling a "request form" for data entry at the user side and submitting all input data at once is more convenient compared to entering single data at a time. Online experiments developed at FSU can be accessed from the URL shown in the list of references[4].

The developed lab experiments are intended to support the introductory level lab experiments on circuits and systems, electronics, and instrumentation. At present, the computer integrated lab facility is utilized at FSU in three levels as described below:
1. *In the laboratory*: Students can use the instruments and experimental setup interfaced to the PC to collect and process data. In this case, students can use existing VI's, or design new VI's by using the LabVIEW® software.
2. *In remote classrooms*: Online lab experiments make it possible to import experimental activities to any classroom with an Internet access, without moving lab equipment. Online experiments can be projected to a screen for class demonstration, or can be accessed by students as a part of classroom activities. Particularly computer labs, mobile PC carts, or laptops are convenient for this type of activity.
3. *At home*: Students can access the online lab any time from their residence to repeat the experiment and practice further, to run additional experiments, or to obtain additional data they might need for their lab reports or homework assignments.

Currently the developed online experiments are being tested on site for educational effectiveness, reliability, safety, and security. The ultimate goal of the project is to enable the students of collaborative engineering programs to
- Physically access specialized laboratory equipment on different campuses through the Internet in real time.
- Actively participate in lecture experiments performed in courses offered over distance by processing and analyzing data obtained in actual experiments.

The developed online lab facility can also be used to offer web based technical courses to other campuses of the University System of Maryland, or open to public for distance education.

IV. Comparison of Different Experimentation Methods

In engineering education, students can gain experimental background in different ways as shown below.

- Individual design projects
- Guided lab experiments
- Computer simulations
- Classroom demonstrations

The common objectives in all these activities can be summarized as "learning by doing" and "learning by watching." At a first glance, computer can be seen as a support to conventional instruments to improve the speed, sensitivity, and accuracy of the experiments. However a PC, which is interfaced to the lab equipment, adds so extensive possibilities that "computer integrated experimentation" can be considered as a new approach in experimental learning.

Computer controlled instrumentation and remote access to such equipment to collect data have been used in the industry for many years. SCADA (Supervisory Control and Data Acquisition) systems used by utility companies, process control systems, and unattended control rooms are some examples. Implementation of computer interfaced instruments in undergraduate education has become possible after they became available at affordable prices. Due to the extremely fast progress in the computer industry, the cost of computer based equipment has dropped to a level comparable or even lower than other elements needed in an average laboratory.

Several papers[5-8] presented in recent ASEE meetings and professional journals describe various virtual and online lab facilities used for undergraduate engineering courses. A variety of hardware and software needed for such infrastructure is now available and affordable. Educational aspects and implementation of computer integrated experiments in either actual or virtual classrooms are therefore more important than building the physical facility.

In an educational experiment, the principal goal is to demonstrate physical phenomena to the students to help them understand the underlying concepts and rules. During experimental work, students also gain hands-on experience and learn important professional skills. The major elements of an educational lab experiment are listed in the first column of Table-I. The effectiveness of an experimental activity in respect to each one of these elements is represented by bullets shown in corresponding cells. This assessment is obviously quite subjective, and its accuracy can be discussed. However, the purpose of this table is to compare the educational effectiveness of different experimental activities. The evaluation shown on Table-I is based on the following assumptions:

- In all activities, average level undergraduate students and realistic laboratory conditions are assumed.
- Individual design project is performed by using conventional (not computer interfaced) equipment. The project topic is development of a working prototype. Student chooses and finds the equipment, material and components.
- Guided lab experiments with conventional instruments are performed individually or as a team in a limited time.

- SPICE® or "Electronics Work Bench®" type simulation software with graphical interface is used for computer simulations.
- Classroom presentations are prepared by the instructor, and conventional instruments are used. However, the collected data values are assumed to be more reliable than an individual experiment, because they are controlled (or checked) by the instructor. Important observations are highlighted and explained by the instructor.
- On-site CIE means use of computer interfaced instruments in a lab environment where students actively work on experimental setup in the same way as a guided lab experiment.
- On-line CIE is remote access to the experimental setup via the Internet.

Table-I Comparison of different experimental activities

	Individual design projects	Guided lab experiments with conventional instruments	Computer simulations	Classroom demonstrations	Computer Integrated Experiments	
					On site	On Line
Selection of instruments	••••	••	-	-	••	-
Selection of components and material	••••	•••	••	-	•••	-
Building of experimental setup	••••	••••	•••	-	••••	-
Debugging	••••	••••	••••	-	••••	-
Dealing with environmental conditions and disturbances	••••	••••	-	-	••••	-
Instrument setting and adjustment	••••	••••	•	-	••••	••
Data collection	••	••	••••	••	••••	•••
Numerical processing of obtained data	••	••	••••	••	••••	••••
Analysis and interpretation of the results	••	••	••••	•••	••••	••••
Understanding of physical concepts	•	•	••••	•••	••••	••••
Presentation of experiment results	•	•	••••	•	••••	••••

As seen on the table, "on-site CIE" is the most effective experimental activity. This type of experimentation requires a computerized workstation for every one or two students, which means a considerably high infrastructure cost for large number of students. Teams of more than

two students are in general not efficient. Computer simulations and on-line CIE are cost efficient solutions to provide experimentation opportunity to a large number of students. Asynchronous learning is an additional benefit of these methods. They are also time-efficient because students do not spend time to build, check, and debug the test setup. Development of hands-on experience and professional skills is however very limited. Conventional guided experiments and design projects provide this kind of experience, but very often the student may be overwhelmed with practical details such as wrong circuit connections, bad contacts, electrical or acoustic noise, broken equipment, etc. In the rush to finish the experiment in a limited time frame, the student might miss some important observations. The classical "pencil based data acquisition" reduces the sensitivity of the recorded data, as well as the quality of numerical calculations, analysis interpretation, and presentation of the experiment results.

V. Conclusions

Experimental learning is one of the important components of engineering education. The effectiveness of experimental activities is different for each element of experimental background. Computer interfaced instruments reinforce the educational effectiveness of conventional lab experiments, but also increase the infrastructure cost. Computer simulations and online labs are cost-efficient ways to provide asynchronous experimentation opportunity for large number of students. By using computer-interfaced instruments, students can store experimental data in high precision for further analysis and interpretation. Computer integrated experimentation is more effective in observation of complex phenomena, and understanding of physical concepts.

Acknowledgment

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