2006-850: FEASIBILITY OF TOTALLY DISTANCE-ORIENTED EET/CET PROGRAMS

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Feasibility of Totally Distance-Oriented EET/CET Technology Programs

Abstract

This paper addresses the problem of delivering an effective "hands-on" learning experience in a purely distance education program within electronic engineering technology (EET) and computer engineering technology (CET). Experiential learning has long been considered to be a necessary pedagogical component in engineering technology. It is generally accepted that a graduate needs "hands-on" experience to be successful as an entry-level technologist in industry.

An examination of undergraduate programs offered in a distance education format reveals that engineering technology programs are conspicuous by their absence. We believe this is because there are no established means to deliver the "hands-on" experiential or laboratory component remotely. While much progress has been made in distance laboratories (virtual and remote-controlled), they do not, as yet, represent an acceptable replacement.

When faced with the need or opportunity for a distance engineering technology program, institutions have addressed this by creating hybrid courses. Delivery of the lecture content is typically done in a format similar to what other disciplines do, i.e. internet-based video (synchronous or asynchronous), downloadable documents, discussion forums, email exchanges, all structured within a course delivery system.

The experiential component is delivered by requiring students to attend laboratory sessions in some facility near their location, or to visit the hosting institution at periodic intervals. Instructors are sometimes dispatched to remote locations when required to oversee these activities. These sessions are usually conducted a few times each semester to minimize travel. Multiple experiments are performed during each session which often requires that the sessions last a full day.

Introduction

Is it possible to create a totally distance program with a "hands-on" laboratory component and if so, how can this be accomplished? To address this, the authors focused on EET and CET programs. The electronics discipline is an attractive choice because relatively low cost components, devices, tools and measurement instrumentation are available. The authors investigated the available technology and hardware capable of providing a combination of "hands-on", remote-controlled and/or virtual experiments.[1-9] In this paper, we analyze the laboratory component in depth and propose a solution.

Our premise is that the reason there are no purely distance EET or CET programs is because no one has developed a pedagogically effective solution to the laboratory component of the curriculum. The laboratory component is a vital element of all technology programs and EET and CET are no exception. The majority of technical courses taken within an EET or CET program contain a laboratory section that parallels the lecture.

Courses are typically offered as 4 semester credits, and consist of 3 hours in lecture per week plus 3 hours in the laboratory per week. Some institutions count the laboratory section as 1 credit while others make the composite laboratory grade a part of the overall course grade weighted by some percentage, e.g. 25%. Most instructors work hard to synchronize the experiments performed in the laboratory to the most recent topic covered in the lecture. Ideally, the weekly laboratory experiment is designed to reinforce the theory covered in the lecture.

Not all technical courses in the discipline have a laboratory component, nor does TAC-ABET accreditation require it. Moreover, there is no fixed percentage that governs this. However, in keeping with the educational objectives and learning outcomes for technology programs, most institutions, accredited or not, deliver 40% of their courses with a laboratory as part of it. It is this heavy "hands-on" experiential laboratory component, that we believe is the primary barrier to a purely distance program in most technology programs and EET/CET in particular.

Scope of the Problem

To quantify the size of the problem, we focused on the EET and CET programs at our institution. Both are structured with 4-year course plans requiring 130 credits (39 courses) to complete. The courses range from 1 to 4 credits with the majority being 3-4 credits. Table 1 shows a breakdown of the 39 courses into two types: "No Hardware Laboratory" and "Hardware Laboratory Required." The term "No Hardware Laboratory" means that either no laboratory section is contained in the course, or if there is one, the laboratory takes place using a personal computer and is purely software application-based such as a programming course in C++. It is our belief that these kinds of courses are currently being successfully delivered in a distance format by a number of institutions.

Table 1 – EET and CET program breakdown by course type.

Program	Total Courses	No Hardware Laboratory		Hardware Laboratory Required	
		Gen-Ed Math English	Core Courses Programming Lecture-only	Physics Basic Science	Engineering Technology
EET	39	15	7	3	14
CET	39	15	9	3	12

Courses included in the "Hardware Laboratory Required" column are those where largely "hands-on" experiments are done. In our case, this includes a variety of electronic and computer courses, physics and a basic lab science. A quick analysis shows that the percentage for "Hardware Laboratory Required" courses is 38% and 43% for CET and EET, respectively. Since each laboratory course contains 12-15 individual experiments, a distance program would need to deliver a grand total of 180 to 250 experiments; a large development and operational undertaking.

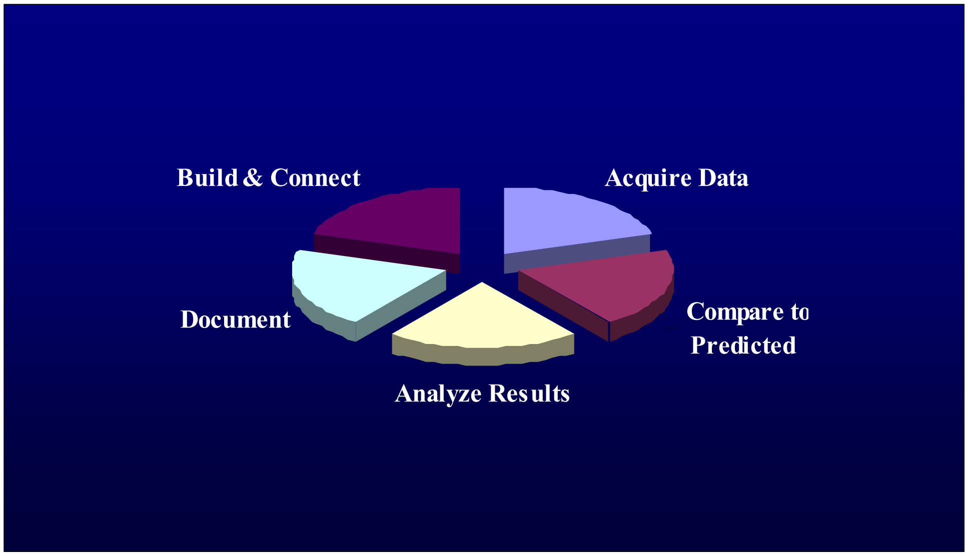
Elements of Experience-based Learning

The concept of distance laboratories continues to receive much attention by researchers.[10-19] Driven by a desire for an experience-based learning solution in distance form, a number of systems have been built, pilot tested and evaluated. Facilitated by the ubiquity of the internet, falling PC costs, advances in application software and the spread of software programming skills (principally Java and Microsoft .NET), more and more work is appearing each year in journals and conference proceedings. While most of the reported systems are developmental projects by motivated faculty, it is only a matter of time before a robust, commercially-viable solution appears on the market.

Is it possible to develop a purely distance EET or CET program via some form of distance laboratory. We think not, and have not found a single educator who thinks so. There is a "hands-on" component that is integral to the laboratory experience that is inescapable. Does anyone believe, that a graduate who has never seen, touched, or handled electronic components and measurement hardware or has not built breadboard or prototype circuits is equipped to enter the technology workplace?

To move beyond this point, we decided to break the laboratory experience into the sub-tasks that are typically performed. In the area of electronics and computer engineering, we found that they fell into five areas as shown in Figure 1. The "hands-on" activities take place in two places: "build and connect" and "acquire data". We made no attempt to quantify the relative time or level of effort spent in each task.

Figure 1 – Breakdown of "hands-on" laboratory tasks.



Our next step was to break each task into specific learning outcomes. Table 2 shows these learning outcomes, the tasks associated with them and whether they seemed achievable via on-line or on-site delivery or both. We found nine of the fourteen outcomes could be achieved by either method; however, four could only be achieved on-site. For learning outcomes associated with the design of a circuit schematic, we saw some potential for on-line delivery. This would require a distance laboratory system capable of physically inserting specific components based on a design input by the student. This would imply some type of component-level switching system that seemed complex.

Table 2 – Electronic laboratory learning outcomes.

Learning Outcome	**Task Breakdown**	**On-site**	**On-line**
1. Read/design schematic (analytical lab)	Build & Connect	√	√
2. Design schematic (design lab)	Build & connect	√	?
3. Provision components	Hands-on	√	X
4. Construct breadboard	Build & Connect	√	X
5. Troubleshoot breadboard	Build & Connect	√	X
6. Set-up measurement equipment	Acquire data	√	√
7. Acquire measured data	Acquire data	√	√
8. Perform other observations	Acquire data	√	X

9. Populate data tables & graphs	Acquire Data	√	√
10. Calculate predicted values	Compare to Predicted	√	√
11. Compare measured & predicted values	Compare to Predicted	√	√
12. Analyze results	Analyze Results	√	√
13. Draw conclusions	Analyze Results	√	√
14. Write up lab report	Document	√	√

Proposed Laboratory Solution

Prior to developing a solution for a purely distance program, we thought it useful to examine all of the known alternatives capable of delivering a "hands-on" laboratory experience for situations where on-site weekly attendance is not possible. To our knowledge, there are three as shown in Table 3. The first two alternatives have been reported by institutions that decided to reach a student constituency unable to regularly attend an on-site laboratory.[20-22] These are best classified as hybrid solutions since both require that students and/or instructors travel (albeit monthly) to a physical laboratory somewhere. For any institution considering a distance program, these two alternatives are attractive since they are successfully being used and are certainly capable of satisfying all fourteen learning outcomes. However, they are not the solution for a purely distance program.

Table 3 – Hands-on laboratory alternatives.

Approach	**Advantages**	**Drawbacks**
Monthly "cluster" week-ends	- Efficient use of student's time - Full day immersion in the lab	- Labs not coincident to lecture - Multiple labs done in a short span
Use local labs on weekly basis	- Weekly access to a laboratory - Labs tightly coupled to lecture	- Requires equipped local labs - Requires instructors be onsite
"Student owned" laboratory	- Students perform labs weekly - Labs tightly coupled to lecture - Can be done when convenient - Students work at own pace - Students become self-reliant	- No "in person" instruction - Instruction support is limited - No face-to-face interaction - Test equipment is limited - Cheating or inappropriate help

The third option is a "student owned" laboratory whereby students are equipped with the components and equipment necessary to perform experiments at their location. Several researchers have reported work in this area.[23]-[24] Technical support is provided in various forms for those requiring help. At first glance, this may seem like an outrageously expensive option, but advances in recent years have made this more feasible.

This alternative satisfies the need for a purely distance program. However, it has its drawbacks as shown in the Table 3. Of most concern are: no "in person" instructor support and test equipment limitations. Both of these issues need to be addressed to make this option effective. A potential solution to the instructor interaction issue could be a teaching video either live/interactive or recorded/playable on demand. To overcome the test equipment issue, we propose an interesting solution: use on-line remote experiments in those cases when students need access to highly specialized or costly equipment. The equipment could be shared across many students since it would be available on-line 24 hours/day.

Experiments generally fell into one of two types: "analysis" and "design". In "analysis" experiments, students are provided a circuit schematic and expected to build and measure a series of parameters. They compare these results with predicted values based on theory. With "design" experiments, students are provided performance requirements and expected to design and build a circuit that meets them. Their results are compared to the original design requirements.

The last two years, we have successfully used on-line remote experiments as a supplement to traditional on-site experiments. We found them to be particularly suited to "analysis" experiments. They were not useful for "design" experiments. It is easy to pre-build a test circuit and make it available for an on-line "analysis" experiment". However, making a full range of components available on-line and in real-time for a custom-designed circuit is a complex undertaking.

Our distance laboratory solution then consists of a blend of on-site and on-line experiments. By "on-site", we mean at the student's location and using equipment provided to them. Table 4 shows how these two types of experiments could be blended during the course of a 15 week semester. In a typical course, the student would complete up to twelve on-site experiments and up to three on-line. The on-line experiments would be of the "analysis" type and/or involve specialized equipment.

Table 4 – Blending on-site and on-line experiments.

Type of Experiment	**Week of Semester**						
	1-2	**3**	**4-6**	**7**	**8-10**	**11**	**12-15**
Hands-on On-site	√		√		√		√
On-line Remote or Virtual		√		√		√	

After examining the course descriptions, topics and specific experiments now performed on-site in our programs, we believe two laboratory packages would be required. The first package, referred to as the fundamental laboratory package, would support a student during their first two years of the EET/CET program. During these years, the primary objective would be to build and strengthen their skill in analog and digital circuit fundamentals. Experiments would not require sophisticated and high speed measurement equipment. The second, an advanced laboratory package, would enable the student to complete the final two years of the program and include more advanced measurement equipment. By using two laboratory packages, costs are spread over time and are incurred only when the students progresses.

What should be included in the fundamental laboratory package? We found an interesting solution with the NI-ELVIS system. Figure 2 shows a picture of an NI-ELVIS system with a breadboard circuit built on it. It offers ten instruments that interface easily via a data acquisition card to a personal computer (PC). Control of instrument settings, data acquisition and file management are simple. While its frequency range is limited and signal levels are restricted, it is a viable platform for the first two years. Table 5 shows the specific NI-ELVIS instruments and their operating ranges.

Figure 2 – NI-ELVIS system with a breadboard circuit.

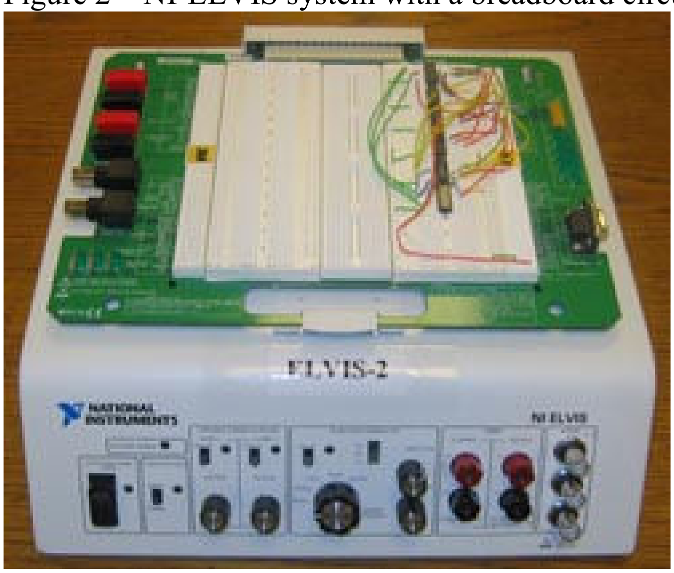


Table 5 – NI-ELVIS instruments and operating ranges.

Instrument	**Range of Operation**
DC Power Supply	±15V, <500mA +5V, <2A Variable ±12V

Function generator	Sine/square/triangle waveforms 5Hz-250KHz ±2.5Vp amplitude ±5V DC offset AM/FM modulation
Arbitrary Waveform Generator	2 channels, ±10V
Digital Multimeter	DC voltage (±20V) AC voltage (±14Vrms) Current (±250mA) Resistance (5-3Megohm) Inductance (100µH-100mH) Capacitance (50pF-500µF) Continuity (max 15ohm)
Oscilloscope	2 Channel, <50KHz, ±10V DC to 100KHz Max 25mA drive 1.5V/µs slew rate
Bode Plotter	5Hz to 35KHz
V-I Analyzer	±10V ±10mA NPN BJT only
Dynamic Signal Analyzer	±10V, 12 or 16 bits
Impedance Analyzer	5Hz to 35KHz
Digital Read/Write	8 bits

To supplement the NI-ELVIS system, students would be shipped a PC with the data acquisition card and NI LabVIEW software pre-installed. The NI LabVIEW software would support local experimentation and be used in a LabVIEW programming course later in the program. The PC would be loaded with any necessary software package to support other courses such as PSpice, AutoCAD, C++/Visual Basic (MS Visual Studio) programming.

A tool kit would be provided to equip a student with hand tools, components and supplemental supplies. Students would use the tool kit to physically construct the required breadboards. The contents of the tool kit would be:

- TI-89 hand-held calculator
- Digital multi-meter
- Circuit breadboards
- Instrument Leads
  - 10x O-scope probe (2)
  - Alligator lead set (4)
  - BNC-IC hook set (4)
- Hand tools
  - Soldering iron
  - 7 in 1 tool
  - Long nose pliers
  - 4 in 1 screwdriver set
  - Slotted screwdriver
  - Phillips screwdriver
- Electronic Components
  - RLC passive components
  - Solid state devices
  - Mechatronic sensors and actuators
  - Motors, tachometers, shaft encoders
  - LEDs, detectors, optical fiber
  - Analog & digital ICs
  - Wire, connectors, clips etc.
- 3-Tray tool box

To support the 3rd and 4th year of the program, an advanced laboratory package would be required. This package would enable a student to work at higher frequencies, wider operating ranges and gain hands-on experience with truly commercial test equipment. The proposed advanced laboratory package would consist of five test and measurement units plus a microprocessor trainer.

We recognize that additional equipment may be required depending on the technical electives or area of concentration a student chooses to pursue. This could be supplied on a course-by-course basis and in some cases, remote on-line experiments could be used to make expensive equipment available (e.g. vector network analyzer). In other cases (e.g. a networking course), most of the experiments could be accessed via distance. Table 6 shows the proposed contents of both the fundamental and advanced laboratory packages as well as specialty equipment for technical electives.

Table 6 – Fundamental and advanced laboratory packages.

Program Year	**"Student-owned" Lab Provisions**		
Fundamental (1st-2nd year)	Tool kit	PC+DAQ card	NI-ELVIS system
	NI LabVIEW	Microsoft Visual Studio/C++	Java development kit
	Allen Bradley PLC software	OrCAD Pspice	NI Electronic workbench
Advanced (3rd-4th year)	DC power supply	PC-based logic analyzer	50 MHz oscilloscope
	Digital multimeter	Arbitrary waveform generator	Microprocessor trainer

Specialty Equipment	DSP	FPGA	Wireless
	Telecom	Microwave/satellite	Networking

Costs and Trade-offs

We combined the contents of both laboratory packages with some specialty equipment and estimated the overall direct cost. To address the need for hardware technician support (maintenance, returns, limited break/fix, etc.), 20% of the direct cost was added for each of the two years. Table 7 is a breakdown of these costs.

Table 7 – Direct costs of the laboratory packages per student.

Program Year	Purchase Cost	Technician Support	Total
1^{st}-2^{nd} Year	$5,500	$2,200	$7,700
3^{rd}-4^{th} Year	$6,500	$2,600	$9,100
Specialty Equipment	$2,500	$1,000	$3,500
Total direct cost	$14,500	$5,800	$20,300

We recognize that a more robust analysis is required to refine these costs estimates. Clearly, there are cost savings associated with not building, maintaining and operating a full complement of on-site laboratories. These savings depend on the current state of the institution, its fixed asset base, projected enrollment growth and capital investment needs.

Can a distance education program be successful? Evidence has shown that high performing students are much more likely to be successful in a distance education program.[25-29] Entrance requirements may need to be higher than a typical on-campus program. Screening of students during the application process could help identify those who are motivated to succeed in an independent environment.

To offer an entirely distance education program requires a significant commitment of resources. Up front investment is needed for course development, faculty training, equipment acquisition, laboratory development and faculty release time. Also of note is that several institutions report that distance education courses require more money to develop, deliver and maintain than on-campus courses.[26-27]

Conclusions

We believe a totally distance-oriented EET or CET program is on the horizon. Using courses that contain both on-site and remote access to equipment, we believe such a program can be successful. Although untested as a complete program, the “building blocks” are in place.

We propose a “student-owned” on-site laboratory that contains all of the hardware and software packages required over a four year program. Our approach spreads cost over time and keeps the functionality of the equipment in line with the student’s abilities and the near term learning outcomes expected. Further, we propose that portions of the laboratory experience be provided by remote-controlled or virtual on-line experiments. Two laboratory packages, fundamental and advanced, were specified. The total direct cost (purchase cost plus operating support) was estimated at $20,300. This equates to $156 per credit which is a significant cost to recover although some portion could be offset by operating fewer on-site laboratory facilities.

We expect the cost of both laboratory packages to decline over time. Assuming PC-based instrument hardware continues to improve (higher bandwidth, better accuracy and more functionality), we believe in 5-7 years, a single laboratory package could be possible reducing the overall direct cost to $12,000-$14,000. In a few years, a few early adopting institutions may appear. They will likely be seeking a long term global strategic advantage and/or be subsidized to deliver totally distance programs.

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