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Teaching Laboratory Courses Using Distance Learning Technologies

Steve C. Hsiung and John M. Ritz

Abstract

Conducting laboratory activities is essential for teaching and learning in engineering and technology subjects. This article discusses explorations made by a research team to find solutions to enable the distance-learning delivery of laboratory courses on embedded microcontroller technology topics. In addition, this article includes a review of videoconferencing and course management tools, uniquely designed laboratory equipment and supporting curriculum materials, and statistical evidence showing students can learn technical laboratory content in distance-learning environments.

1. Factors Affecting Successful Delivery of Laboratory Courses Using Distance Technologies

Distance learning (DL) has become a common instructional delivery system in higher education and corporate training. As a result, post-secondary colleges and universities had offered over 100,000 e-learning courses by 2005 (Keenan 2010). For many learners, computers have become a means to access higher education. The main requirement has been for learners to find distance courses or programs and have a computer with an Internet connection to receive the instruction.

DL has grown in popularity for several reasons, including a lack of access to local college campuses, the need for colleges to generate revenue by offering high need or specialized programs, colleges reducing costs of building additional classrooms/laboratories while continuing to offer highly sought-after courses/programs, student time conflicts due to work commitments, and faculty exploring DL options for delivery of their courses. With most DL courses, content is stored on a server, where learners can access courses at convenient times, 24/7 (Lewis and Levin 1997).

However, distance delivery can be difficult for engineering and technical programs, due to problems associated with teaching technical concepts/labs necessary for student understanding and learning. With advancements in information technology infrastructure and software applications, using the Internet to deliver technical content has become more practical (Morrison and Ross 2007). To enable faculty to reach digital learners and possibly attract them to STEM-related career programs, engineering and technology faculty might be able to offer more courses/programs through DL formats. This article reports faculty experiences in finding solutions to teaching embedded microcontroller technology topics via real-time DL teaching.

Engineering and other technology programs require students to learn new knowledge and understand its application to the operation of technical systems. Laboratory learning aids students in seeing how technical processes work. These activities enable faculty to better educate learners regarding the knowledge and abilities required to practice their professions. However, using DL techniques for teaching hands-on laboratory activities can pose challenges for faculty, students, and delivery systems. To adapt technical programs to the needs of learners, teaching practices have evolved that parallel or extend beyond traditional face-to-face laboratory settings (Hsiung, Ritz, and Eiland 2008). The application of DL technologies to laboratory courses can expand opportunities for students seeking these types of college curricula.

By better understanding the technical requirements of DL technologies, knowing how others have approached distance learning in engineering and technology courses, and identifying campus support services can aid faculty as they evaluate distance delivery as a possible learning modality. Through exploration and experimentation, along with learning about campus infrastructure for supporting DL, faculty can become more comfortable with this type of delivery, plan curricula, and offer engineering and technology courses.

Both authors have used various distance delivery systems. Our first experiences were delivering courses via one-way video with two-way audio in a real-time televised teaching environment. Recent experiences have included two-way televised delivery of audio and video to blended hybrid types of delivery, where part of the lecture/demonstration is televised (or video-streamed), while parts of other lessons depend on traditional Web-based online delivery methods. Both faculty are currently using Adobe Connect to supplement instruction and plan to teach some courses using only video-streaming technologies (Hsiung et al. 2010).

In a traditional learning environment, faculty provide instruction (lecture and demonstrations) to explain new knowledge and assign projects, labs, or other activities that are due on specific dates to reinforce the learning experience. Students who attend a face-to-face class, either in the presence of an instructor or via distance technologies, usually learn at their own pace during and after a lecture and reinforce the knowledge by reviewing notes, reading book chapters, asking instructor and peers questions, and during their lab work sessions.

In a DL course, faculty can deliver knowledge in different formats. Many use online postings for student to read and work through questions. Some systems have one-way or two-way audio-video transmissions, while others use one-way video and two-way audio. Systems that use audio video (AV) presentation formats can be archived into a database that students can access later, so they can review stored information when working on assignments.

Both face-to-face and DL formats can provide the same learning opportunities for students (Means et al. 2009), and faculty can provide collaborative experiences for sharing personal knowledge and experiences. Students can communicate through instructor-established groups, and faculty can assign team projects. In distance courses, faculty and students can communicate using email, Skype, telephone, or other technologies, in addition to the audio-video transmitted sessions.

Distance learning, also known as distributed learning or cyber-enabled learning, “refers to technology-mediated instruction that serves students both on- and off-campus, providing students with greater flexibility and eliminating time as a barrier to learning” (Oblinger, Barone, and Hawkins 2001, 1). It can be used as an alternative to or concurrently with face-to-face campus-based learning. It is not meant to replace the campus-learning environment, but it can become an optional learning modality for larger numbers of non-traditional students (Bernard et al. 2004).

Active DL, where faculty and students communicate real-time via electronic means, can provide for quality interactions between students and instructors and occur much the same way as in a regular classroom; however, students are in an electronic classroom/lab environment along with the instructors. Active DL environments typically capitalize on high-speed Internet connections using real-time video lectures and demonstrations, including computer video-streaming or conferencing applications (Hsiung et al. 2009). Adobe Connect Pro, GoToMeeting, MSN Messenger, Yugma, Google Chat, Skype, and Cisco Jabber are common commercial video-streaming and conferencing applications.

Since the outcomes for distance classes should be the same as those for face-to-face lecture/laboratory classes, planning and delivery should also be similar, except planning for DL courses usually requires additional details. Implementing instruction in an active DL environment requires the coordination of instructional materials and delivery technologies. Students might need copies of instructional materials (such as notes, handouts, graphs, photos, video demonstrations, circuits, or equations), login capabilities, a means for taking tests, and systems for delivering assigned materials and projects/labs to faculty. Software to complete courses should be available as student versions or through a virtual lab setting.

Discussion forums, the electronic ability for faculty and students to chat, can be held on-line and designed as a learning resource for questioning, collaborative learning of difficult course materials, sharing personal experiences, or mentoring (Isbell 2005). Depending on the instructor’s philosophy and course practices, students might be required to participate in discussion forums, and the instructor may closely monitor these discussions, requiring students to follow established protocols. Students could post as well as answer questions. A discussion forum can provide students with a resource to supplement course materials and ease the load of the instructor for repeating answers to similar questions from a number of students.

Scheduled real-time instructor-student meetings, e.g., office hours, are an important dimension that can enhance the quality of a distance course. These meetings can be required and have a number of goals:

- to ensure the continued integrity of the learning process and maintaining student focus, thus improving knowledge acquisition
- to monitor student progress
- to allow the instructor to assess student level of understanding
- to identify course materials for review or topics to revisit
- to provide an opportunity for instructors to know each student better
- to provide special assistance where needed (faculty mentoring)

- to review student performance on homework, lab exercises, projects, and tests

Using the telephone or a webcam for chats can be useful for answering specific questions or solving problems students may encounter with course content, formula solution, or project/lab advising and troubleshooting. Webcams can be set up on tripods so the instructor can view student projects or offer troubleshooting suggestions.

Distance learners frequently have out-of-school responsibilities, such as family and work. DL technologies allow real-time lectures and group discussions to be recorded and archived, so students who miss a class could view it later. Or if students have difficulty understanding the material or need to check assignment requirements, they could review the archived lecture. Lessons from previous semesters can be substituted if the instructor is ill or away from campus for professional commitments.

2. Technology Requirements for Distance Teaching of Technical Labs

Depending on the support that colleges or universities offer to faculty for DL, the technologies will affect content delivery. Many campuses use basic support technologies that might limit delivery of laboratory-based offerings. Minimal support would enable a faculty member to host a Web-based course, with the use of course management tools such as Blackboard or Moodle to house course materials. Faculty would be required to post graphics, including photographs, drawings, or laboratory demonstration videos. Faculty could also post videos on YouTube or other websites. If video delivery format is available, a greater variety of teaching activities can support technical course offerings.

2.1 *Video Conferencing and Course Management Tools*

Video hardware and software support can greatly enhance teaching technical content. Examples of videoconferencing systems include Adobe Connect, Cisco Jabber, Google Chat, GoTo Meeting, and Skype. These are common support systems available, either with or without a fee. The use of course management tools is also important for posting course materials such as video/audio files, handouts, discussions, etc. Blackboard or Moodle are common course management tools available on many campuses.

2.2 *Common Instructional Hardware and Software*

Laboratory equipment available to students can improve opportunities for delivery of technical course activities. Not all laboratory equipment is practical for students to have at home or at a regional center. Since the authors of this article knew the technical capabilities needed for students to learn embedded microcontroller technologies, we experimented and developed instructional support training equipment to use with our courses. This was a key for success in implementing a course that required hands-on instruction. Although much heavy mechanical equipment is not realistic for students to have at home, equipment can be designed or purchased to teach many concepts found in power and energy, graphic/multimedia, CAD, and electrical and computer engineering technology courses.

Others might explore the practices followed by the medical communities, where students participate in internships/practicums with medical practitioners for learning the technical practices associated with particular professions. Open University in the United Kingdom, for example, has used business/industry placements for students to learn technical skills needed in their academic majors. This is an option not explored much with engineering and technology. Cooperative placements are close examples of this, but they are industry specific.

If a standard technical teaching platform/equipment is not available for all students, there are many variations with equipment options, but faculty may not be proficient with all of these, leading to difficulty in assisting students when they encounter technical problems. Using a common equipment platform can reduce technical difficulties for both students and faculty (Hsiung, Ritz, and Eiland 2008). We took three years to fully develop the training equipment used in the embedded microcontroller technologies course.

To resolve common hardware and software laboratory equipment disparities, instructors may use commercially available laboratory kits/trainers for distance laboratory technical activities. Equipment selections require evaluation by faculty, since cost can be an obstacle for students. A custom-made hardware platform that meets course content needs, at a reasonable cost, may be a key element to the success of distance laboratory-based courses.

2.3 *Understanding Delivery Requirements*

Faculty need to meet with campus DL professional staff to review the teaching tools available on their campus before deciding to offer a course in a distance format. Controlling several electronic files with different software tools, while teaching real-time, having active discussions, or establishing groups or one-on-one meetings, can be challenging, and faculty need to feel comfortable with the technology. Campus training does help in preparation, but comfort in distance delivery is established through actual use. Faculty can gain confidence by practicing with colleagues or graduate students before live delivery. However, technical system problems will undoubtedly arise, causing experienced faculty to troubleshoot. If campus technicians have oversight of the delivery system, they can manage and solve delivery problems. In addition, students need to be proactive in learning how to use the course tools. Faculty may require students initially to spend time in and out of class learning how the delivery system operates on their computers when courses begin. Resolving issues via real-time meetings and discussion board postings also requires practice and preparation, just like using a new software system.

Figure 2. Classroom and televised lecture.

3. Reflections on Laboratory-Based Distance Delivered Courses

Through the assistance of a National Science Foundation grant, the authors developed a peripheral interface controller, or PIC (Microchip 2010), training system with a supporting curriculum package for use in teaching laboratory-based embedded microcontroller technology courses for electrical engineering and technology programs. The PIC system has been used with televised DL, Adobe Connect conferencing software, and campus-based courses. The grant allowed us to design and manufacture a common embedded microcontroller technologies teaching platform, along with supporting instructional materials, such as teaching notes and laboratory manuals.

Figure 1 illustrates the PIC training platform used for the hands-on laboratory portions of these classes. Supporting curriculum modules, software programs, and instructional videos were also developed and used for this teaching system. These materials are stored on Blackboard for student and other instructor access. For DL courses, each student is required to purchase the PIC training system hardware platform for $130; the software and curriculum materials are available for free downloading. This custom-designed package has reduced issues in troubleshooting student circuit designs, thus reducing teaching difficulties.

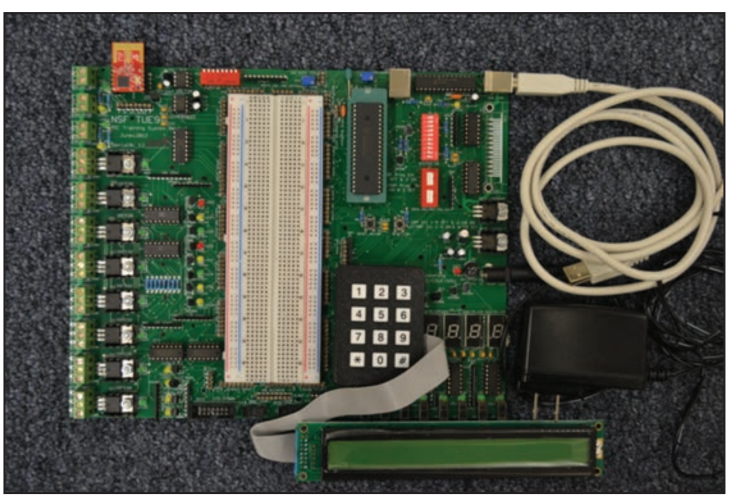

Figure 1. PIC training system.

Figure 2 presents an example of a televised classroom session broadcasted using a satellite connection and video-streaming. It allows for both audio and video communications and is transmitted to community college receive sites, where the university has lease agreements for classrooms. The transmissions are also video-streamed, so students who are not near a site can take classes using their own computing systems. All of this instruction is real-time. A three-hour/week lecture format is used for microcontroller programming and embedded systems design. Archived videos of the class are available for later review. To see an example of a televised and video-streamed course, go to http://vimeo.com/25007880/; this segment shows the use of technical equipment, software applications, and real-time laboratory demonstrations.

Class discussions using Adobe Connect are required to clarify information or answer questions students encounter during laboratory activities. Laboratory demonstrations can take place real time. An example of a video illustrating a real-time instructional session using Adobe Connect can be seen at the following link: http://connect.odu.edu/p30278824/. As shown, information on the desktop computer on either end of the transmission can be shared during the session. The recorded discussion link from this meeting is available and posted on Blackboard for review.

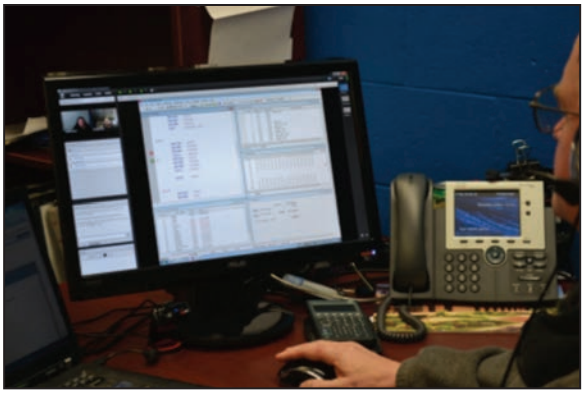

Figure 3. One-on-one meeting.

Figure 4. Lab/project performance check.

As an added teaching resource, students might be required to sign up for 10-15 minute individual meetings with the instructor, or faculty can check individual student progress using the learning modules and training equipment, which is similar to having a face-to-face meeting. Figure 3 demonstrates the use of Adobe Connect for a real time appointment between an instructor and a student. Figure 4 shows a faculty member reviewing a lab/project activity. To see a sample tutoring session using Adobe Connect, go to http://connect.odu.edu/p98538907/. Special one-on-one sessions using Adobe Connect can be made directly with the instructor via telephone or email correspondence.

Discussion boards allow for review of topics related to lectures or lab assignments. These can take place in on-line formats using Blackboard, and the instructor can monitor the discussions to maintain content integrity. Lab discussions using group leaders assigned by the instructor on a rotating basis can be setup on Blackboard to assist students in understanding laboratory assignments. To ensure student participation and increase understanding, after the completion of each lab faculty can use email for lab tests. To further assist student understanding, group leaders could be held responsible for managing group lab discussions and assisting students to solve individual problems. A group leader's lab test scores could be calculated based upon the average scores of group members.

Attendance for class and/or lab topic discussions via Blackboard might contribute to a student's final grade. Faculty can review a final lab project and assess understanding by meeting with each student via Adobe Connect. Phone and email can be used as backups for problem solving. At institutions participating in this NSF-funded project, students are now able to complete more lab activities using the PIC training system.

4. Statistical Evidence of Project Success

The PIC training system designed for this project was evaluated in different ways to determine its success for teaching both face-to-face and distance. Participating faculty used the equipment and supporting instructional materials at three different professional development workshops, where they learned about the system and evaluated its usefulness. In addition, three external reviewers evaluated the training system. Faculty and students at three community colleges, in addition to the host university, used the system in both

Table 1. Summary of faculty and evaluators responses.

#	Topic (analyses based on 5-point Likert scale)	Total Average
1	Quality of hardware and software designs of the PIC Training System	4.98
2	Cost competitiveness with a $130 price for the PIC Training System	4.99
3	Ease of use of the PIC Training System using a common training platform for course exercises; ease of trouble shooting in design projects	4.82
4	Distance learning cost effectiveness for the PIC Training System	4.31
5	Quality and effectiveness of supporting curriculum materials for a variety of courses	4.65
6	Benefits of additional wireless communication and control	4.00

Note: Statistics reflect scores from a 1-5 point Likert-scale. A score of 5 is the most positive value.

Table 2. Instructional topic/module evaluations.

#	Instruction Module	AA Campus 3 Students	YYY Campus 14 Students	ZZZ Campus 13 Students	XXX Campus 33 Students	XXX Distance 25 Students	Over-all
1	Institution Course(s) Involved	ELECT 227/237 228/238	ETR 273/274	ETR 261	EET 320/325	EET 320/325	N/A
2	Curriculum Modules Covered	1-8	1-8	1-7	1-11	1-11	N/A
3	Microcontroller Technology	4.63	4.24	4.77	3.84	4.37	4.25
4	Number Systems	4.96	4.09	4.78	4.63	4.78	4.58
5	Assembly Language	4.58	4.09	4.46	3.96	4.71	3.88
6	I/O Interface Controls	4.72	3.97	4.13	3.72	4.56	4.35
7	Software Designs	4.84	4.27	4.50	4.00	4.56	4.15
8	Uses of Watch Dog Timer	5.00	4.43	4.73	4.25	4.80	4.53
9	Using IRQs	4.67	3.61	4.27	3.60	4.38	3.98
10	Parallel Data Communications	3.67	3.62	N/A	3.85	4.26	3.94
11	Matrix Keypad Interface Designs	4.38	3.29	N/A	3.73	4.31	3.87
12	Trainer Hardware and Software	3.13	4.28	4.52	4.20	4.63	3.93

Note: Statistics reflect scores from a 1-5 point Likert-scale. A score of 5 is the most positive value.

face-to-face and DL formats. Evaluations showed the PIC training system was affordable, provided increased microcontroller functionalities, and had course materials that supported academic needs. The evaluations cited additional teaching content attributes of the system, and the reviewers also acknowledged the trainer's capabilities and potential for broader use at both 2- and 4-year higher education institutions.

The 36 faculty members who participated in the workshops and 9 faculty who used this training system and curriculum in their teaching felt the system provided enhanced instructional assistance for teaching embedded microcontroller technology topics. Results from an evaluation of the instructional system showed faculty rated the training system above the "agree" level (3.51 on a 5-point Likert-scale) for usefulness in teaching microcontroller system design. See Table 1 for the topics evaluated on the functionalities of the PIC training system.

In addition, 88 face-to-face students used the PIC training system and voluntarily completed assessment surveys to evaluate the appropriateness of the system for instruction. Table 2 summarizes these data.

Statistical analyses were further conducted to examine the benefits to student learning through this instructional system to previous systems used by the faculty members and to observe the statistical differences between the final course grades for student groups. The data support the effectiveness of the training system and its curriculum design; the students' achievements showed a significant difference for those who used this training system compared to those who did not. See Table 3.

Additionally, the grade point averages of students who completed a course through face-to-face instruction taught by the same faculty were compared to the gpa's of students who completed the course through distance learning. The mean course grade for the 30 on-campus students was 88.31 and 92.56 for the 32 DL

Table 3. Statistical analyses in learning achievement.

#	Statistical Analysis	YYY		ZZZ		XXX		Overall	
		W Trainer	W/O Trainer	W Trainer	W/O Trainer	W Trainer	W/O Trainer	W Trainer	W/O Trainer
1	N (Total #)	14	53	13	25	62	195	89	273
2	$\bar{x}$ (Mean)	79.29	81.06	96.15	84.13	90.55	86.62	89.60	85.31
3	t-test Value	-0.57		1.68		2.36		2.73	
4	Level of Significant	1.67, $p<.05$ Not Significant		1.68, $p<.05$ Significant		2.34, $p<.01$ Significant		2.34, $p<.01$ Significant	

Table 4. Comparing face-to-face with distance student performance.

Variables	Number of Cases	Mean	SD
Face-to-Face Instruction	30	88.31	8.13
Distance Instruction	32	92.05	10.98
t value	1.81 (p<.05)		

students. Using an independent t-test, the comparison value of 1.81 was calculated and found significant at the $p < .05$ level at 1.67 ($t(62) = 1.81$, $p < .05$). Data indicate that both groups learned the material, but the DL students' performance yield significantly higher grade scores than those who received face-to-face learning using the same training system. Although this is a start for determining the value of the system for teaching using DL technologies, additional study needs to be undertaken with the use of the system in training both faculty to teach embedded technology courses and student assessments from learning in a distance format. See Table 4.

Why did the distance group perform better? Observations indicate that distance populations are usually more mature (working students who are older) and possess greater intrinsic motivation to succeed in college courses (Bye, Pushkar, and Conway 2007; Keenan 2011; Sorey 2002). This research team found adult students are more motivated and performed better than regular face-to-face students (Hackworth and Jones 2004; Means et al. 2009; Waits and Lewis 2003).

5. Summary

Distance learning does provide options for faculty who teach technical laboratory courses. Although DL is not meant to replace face-to-face instruction, it can be used to teach select technical topics, courses, or programs to students who do not have access to campus learning opportunities. Through planning and design with the support of current DL technologies, more can be done in teaching laboratory-based course content. Important to teaching using DL technologies is the necessity of learning and evaluating components of distance delivery systems. The authors advise proceeding slowly and experimenting while transitioning to DL course delivery. Students do like to take distance delivered courses and can perform well.

Internet technologies are maturing and becoming less expensive. These can handle real-time video and audio course delivery. For digital-age students, delivery options are important to them and their lifestyles. To educate these learners, distance education, with active hands-on real time laboratory instruction, might provide options.

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