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Delivery of Hands-on Technical Courses through Real-Time Distance Learning

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Abstract

It is generally believed that it is too challenging to deliver technical laboratory courses using distance learning technologies. The focus of this research was to develop strategies that may be used to address these challenges. A research team composed of faculty from several universities and community colleges explored what might be needed to make these types of technical laboratory course instruction possible using distance learning technologies. The team explored delivering a microcontroller embedded systems design course through audio-visual distance learning technologies. The team's research and development activities are discussed. These include focuses on the technical training equipment that had to be designed to support the course's microcontroller technologies curriculum and laboratory modules, instructional support videos, and the design of an electronic server system to support this instruction. Also discussed will be the findings from the faculty of other colleges and universities who received professional development training from the research team on teaching microcontroller technology courses using distance learning technologies.

Introduction

The push to move education into using distance learning formats comes from many sources[1,2]. Some are internal, while others are external[3]. In this instance, there were the curiosities of a team of researchers[4], in addition to the push by their institutions to move courses and programs into a distance learning environment. These faculty sought external funding to assist them in their research to find solutions to delivering hands-on technical content courses using the advantages provided through electronic instructional delivery technologies.

The technologies developed and used by these researchers were supported by a three-year, proof of concept, National Science Foundation project. The initial year's work explored the needs for developing such a training platform to use in delivering instruction, so students could participate in laboratory activities guided by faculty, plus an additional design of operational microcontroller circuits. A technical trainer board was developed through an earlier research project (and initial instructional modules were written). Through this project, the total instructional support system was refined, additional learning modules were added, plus a set of laboratory modules were completed. During the project, the instructional system was tested through three summer workshops taught to 60 faculty members (2-year. 4-year, and high school) throughout the U.S. using distance learning technologies. Data collected through the summer workshops has shown that technical laboratory content and courses can be taught using distance learning conferencing instructional systems.

Teaching Platform and Modules

A common hardware platform, or trainer board, was believed by the researchers to be important to the success of this technical course instruction and the overall research project. Each student and instructor involved in the project would have the same technical capabilities when being taught, just like purchasing and using a commercial trainer in an on-campus laboratory course. The research team found that this feature would place all to be taught in the same technical learning environment with regard to laboratory tools that are available to them.

In this case, a PIC training system was designed and developed through the support of a previous NSF supported grant. The refined microcontroller laboratory board has the following features:

1. All component parts are available from vendor purchases.
2. The system could be used with Microchip (PICKit2, PICKit3), NXP/Philips (LPCX), and Arduino systems for programming, simulation operation, and debugging.
3 Power options would included +-5V, +-12V, +3.3V, digital and analog I/O, LCD, and LED displays, RS232 and USB communication capabilities, 2.4GHz wireless module, and high and low power isolation for digital/analog and motor drive control.
4. OPAmp, EEPROM, DAC operations, and SPI Bus would be available.
5. FET/IRF530*8 power for stepper and DC motor controls would be available. [5]

The design of a common teaching platform played a significant role in eliminating technical issues while teaching practical hands-on technical courses[6.] This trainer made the teaching and learning much more convenient for using a distance learning delivery format. Teacher and students had the same equipment. This made student communications and trouble shooting of hardware and software designs the same for all. The custom designed platform also met the academic needs for teaching concepts that needed to be experienced by students to understand microcontroller design systems. The researchers' designed system was also economical for student purchase, approximately $130. No additional textbooks or laboratory manuals were required, since these materials were written and posted on a server for student and faculty use by the research team. It was felt that using this common platform in the delivery of the distance training would add to making the teaching and learning of microcontroller content more successful. Photo 1 shows this PIC training system that was designed and used in this project.

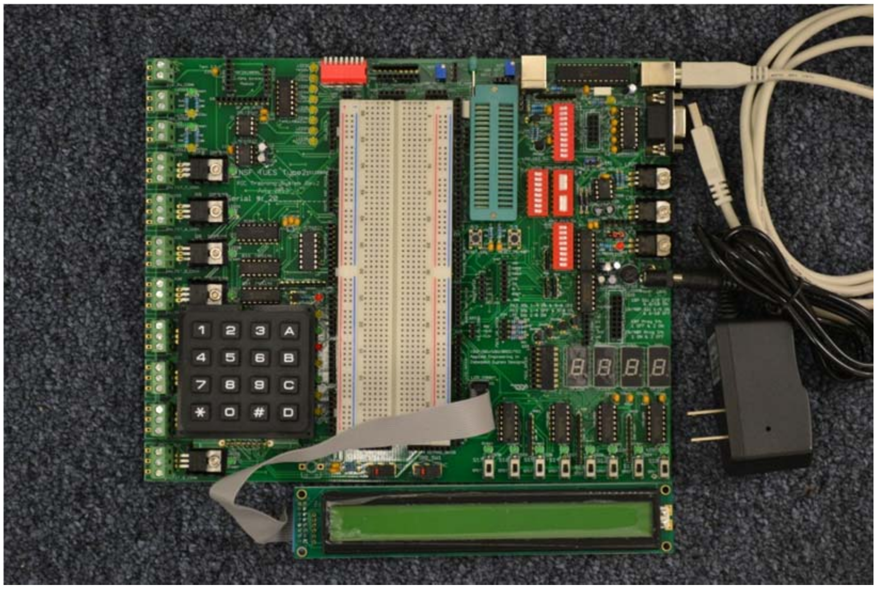

Photo1. PIC Training System

A set of 10 instructional modules were first developed by the research team. Different modules were written by different project faculty. To make them into a workable package, all were edited for similarity in content presentation and each was formatted in the same style.

Although 10 modules have been developed, six additional modules are in working stages; it was not intended that all modules would be taught in one course. During instruction to faculty, seven modules were taught during a three day training session. Faculty have found that they could teach six to eight modules during a semester course for students. The research team's intent was to have sufficient modules to use in several different courses at the 2-year or 4-year levels. See Table 1 for a listing of the developed and projected modules.

Ten laboratory modules have also been developed to guide student application work after the instructor teaches the content through their normal instructional practices. The lab modules are designed to apply and reinforce the content of the instructional modules. The lab modules do provide step-by-step instructions to have students complete laboratory work. In addition there are questions to be answered and worksheets to be used for grading the laboratory work within the laboratory modules. There are also faculty developed videos that show how the trainer is to perform or control other mechanism that support each lab module. These have been found to aid student understanding of laboratory outcomes. Other laboratory modules are planned to align with the 16 content modules.

#	Module Titles	#	Module Titles
1	Microcontroller Technology	9	Stepper Motors Controls
2	Numbers and Programming Languages	10	DC Motors Controls
3	Register and Memory Programming	11	ADC and DAC Controls
4	I/O and Routines	12	Remote Data Logging
5	I/O and Watch Dog Applications	13	Wave Forms Generation
6	Interrupts	14	PWM Module for Motors/Servos I
7	LCD Communications	15	Feedback Loop with IR Sensing and DC Motors
8	Keypad Controls	16	Multiple Processor Communication using a SPI-based Master-Slave Configuration

Note: Modules 11-16 are under development.

Table 1. Microcontroller Curriculum Modules

The application software MPLAB IDE and PICKit2 were used for circuit control and programming in this project. They were selected because they are common to microcontroller programming and are free for use from Microchip (www.microchip.com). These software applications can be used for editing, creating simulations, compiling in Assembly, C, and BASIC languages, and programming. The PICBASIC PRO compiler made by microEngineering Labs Inc. was also used in the trainer design. Overall much research and development were needed to develop and perfect the training platform. Once it was developed it took the skills of curriculum writing to develop the instructor modules and student laboratory modules. Again it also took the knowledge of engineering to program the software to make the system interface correctly for instruction.

Preparation for a Virtual Classroom

Server storage and access issues need to be planned before the actual delivery of a course. Some choose to use campus servers, while others choose to use Blackboard or similar course management applications operated by their schools. This research team needed the capability to have all project faculty capable of uploading content from their institutions, plus have plans for others who might want to post materials related to microcontroller technologies onto the server. University servers have firewalls to protect their servers from outside users. This project had to have access for outside users. The research team wanted to post videos that supported microcontroller instruction and also laboratory demonstrations to support this content. This also required the posting of code, so users could download this for their microcontroller design functions. We chose to use Moodle, an open source course management server service, as its server for course management. The project team purchased its own server. Although BlackBoard and Moodle merged in April 2012, Moodle remains an independent division and continues to serve the educational community in an open source format. Moodle is free, so the project chose it as its course management tool; access by users was a major concern.

The research team also had to choose how they plan to deliver courses via distance learning technologies. Faculty had experience with web-posting of course materials, but they sought to make the project's courses faculty/student interactive in delivery functions. This meant the courses would be offered real-time, with the instructor teaching and the students being about to communicate with the faculty member and other students in class. The researchers had worked with Adobe Connect using real-time distance lectures, conducting lab exercises, conferencing students, and creating audio/video archives.

The project investigator's university has a site license for Adobe Connect and three faculty had taught students using the system. Adobe Connect became the technology the faculty research team used to hold monthly meetings. Each participating faculty member was trained to use this conferencing system at a summer training workshop and then required to use it in monthly research team meetings.

Advantages of this system include its video and audio capabilities. Audio can be controlled and, when desired, students click on an application function requesting permission to speak. The faculty member is in control to allow student conversation to reduce possible audio chatter.

This system also allows the faculty member to focus a video camera onto the trainer, so students can see wiring configurations and watch demonstrations. The video-conferencing application also allows faculty to divide the class into sections, so different groups of students can conference (collaborate) with each other.

The research team found this to be an asset for their teaching, since during summer training of other faculty to teach microcontroller topics, it allowed for teaching using Assembly, C, and BASIC programming languages. The research group chose to teach the main content of the summer training for faculty to all participants at the same time. When it was time to conduct laboratory activities, the class was grouped into three sections, one for each or the programming languages. Participants could then select the language they understood and participate in this particular training. Some chose to learn another language that they planned to teach with in the future.

Another function that Adobe Connect has is its ability to allow for the recording of all training sessions/classes. Faculty can elect to record each class session and then can post the saved content at a generated URL. The faculty can then share the URL with students for their review. This allows students to use the video recording when they are conducting laboratory activities while away from the courses hours. It also allows the faculty member to pre-record a class session if they need to miss class.

What We Learned from This Distance Learning Project

After the training equipment was re-designed and the instructional support package (content modules, laboratory modules, video segments, and codes) was completed and posted on

Moodle, faculty from 2- and 4-year institutions across the U.S. were invited to participate in a 3-day professional development program that would be offered using the Adobe Connect distance learning technologies. The research group's intent was to have faculty learn about microcontroller technologies and to become educated in using this training system for their own students' instruction. The research team first wanted to expand the knowledge of engineering faculty to the content and teaching of microcontroller technologies. Then they wanted to show how such courses could be successfully delivered using electronic instructional technologies.

The team's advertising was focused on three regions of the U.S. – East, Mid-West, and West for 2-year and 4-year institution faculty. Some participants were also recruited from the high school technical teaching population. It was planned to teach 20 faculty in each region through 3-days of training. One hundred eighty applications were received to participate in the training. Follow-up with these faculty found 60 to be committed to the time restraints of the project faculty. Three, 3-day, workshops were planned. These occurred in June and July. There were some faulty who were outside their own specific region, e.g., Mid-West, who participated in the professional development session in another region, since distance was not a factor for participation. The only difference was time zones.

Prior to the start of each workshop, the training equipment was sent to participants so each could test the training system to see how it worked and each participant was requested to log in to Moodle server to review the instructional materials that had been posted for instructional assistance. It was suggested that each participant log into Adobe Connect as a guest before the start of the workshop, so they could learn to use the conferencing technologies to be used for instruction. Various Adobe Connect test training sessions were scheduled.

During the workshops, there was a lead faculty who oversaw instruction, but instructional tasks were portioned out to members of the research team. Each training workshop was taught for 8-hours during each 3-day scheduled workshop, a total of 24-hours of instruction per workshop. Although offered electronically online, the courses were operated similarly to teaching a face-to-face campus course. The mornings began with an open questioning session, objectives for the session were reviewed, and content topics were delivered through a visual/ discussion process, again followed by questions and answers. Instructional videos of the training system were used to further clarify instruction. Close-up video of circuits were used by mounting cameras on tripods. After the content and its major concepts were taught, then the class was divided by language (Assembly, C, and BASIC) for lab instruction. Breaks were also taken just as in other real time classes.

To determine the knowledge participating faculty had of microcontroller topics before the training began, a pre-test was administered. Three days following the workshop, a post-test was administered. The mean pre-test score for the 60 participants was 5.26, while the post-test mean score was 15.45. This was determined from a 22 question test based on the knowledge the research team thought was needed to properly teach microcontroller technologies (module content goals). These results show that on an objective test from the content chosen for this training, little was known about microcontroller concepts before training and sufficient learning did take place through the distance delivered instruction.

Also important was to measure the learner's (1) attitudes toward the technical knowledge taught and learned, (2) opinions regarding the usefulness of the training system for instruction of classes, and participants' (3) interests in teaching technical laboratory courses in the future using distance learning technologies. Ten questions from a follow-up survey were directed to assessing participant's opinions toward their understanding of the content (module goals) for each of the10 modules used in the course. Since only seven of the modules were taught during the summer workshops, the mean scores on these topics were analyzed. The range of mean scores was from 4.52 to 3.59 (based on a scale of 5 for strongly agree) on all seven modules. The overall median score for these module questions was 4, showing that the participants indicated that they mastered the contents of the modules taught. Table 2 is a summary of the findings related to the technical content of the training.

Module Goals – I was able to (SA= 5 to SD = 1):	**Statistics**
1. Describe the fundamentals of microcontroller technology.	M = 4.52, Med. = 5, SD = 0.57
2.1.a. Preform math and logic operations in different numbering systems.	M = 4.23, Med. = 4 , SD = 0.77
2.1.b. Explain basic logic gate operations.	M = 4.49, Med. = 5, SD = 0.63
2.1.c. Program a PIC microcontroller in various numbering systems using mathematics and logic operations.	M = 4.11, Med. = 4, SD = 0.82
2.2. Use STATUS flags to operate programmable intelligent computer (PIC) controlled devices.	M = 4.09, Med. = 4, SD = 0.86
3.a. Explain the PIC16FXX embedded system circuit design.	M = 4.13, Med. = 4, SD = 0.76
3.b. Use I/O pin configuration and control functions with an internal CONFIG register.	M = 4.27, Med. = 4, SD = 0.65
4.a. Explain the use of a flowchart for PIC programming.	M = 3.93, Med. = 4, SD = 1.01
4.b. Calculate and write a time delay loop(s).	M = 4.07, Med. = 4, SD = 0.83
4.c. Identify the ranges and uses of the DM and PM.	M = 3.59, Med. = 4, SD = 1.02
5. Describe the structure, purpose, and potential applications of the WDT timer.	M = 4.27, Med. = 4, SD = 0.67
6. Explain the structure and the application of interrupts, flags, global enablers, and individual enabler setups, interrupt handler hardware and software, IRQ configuration, polling vs. ISR (IRQ service routines), and prioritize IRQ services in the program control.	M = 4.11, Med. = 4, SD = 0.73
7. Use parallel data communication between the microcontroller and other devices such as a LCD module.	M = 4.14, Med. = 4, SD = 0.80
8. Use a matrix keypad interface.	M = 3.91, Med. = 4, SD = 0.94
9. Use hardware/software for programming, interfacing, and testing with uni-polar and bi-polar stepper motors.	M = 3.38, Med. = 4, SD = 1.07
10. Use hardware/software for programming, interfacing, and testing with DC motors.	M = 3.27, Med. = 3, SD = 1.09

Table 2. Opinion Survey Results Course Technical Content Mastered

Also important to report is the opinions of the workshop participants on their impressions of the training provided by the research team. Survey Question 11 asked, “What is your overall impression of the course modules for assisting you with understanding embedded technology knowledge and applications?” The mean for this question was 2.0 (2 indicated mostly positive, while 1 indicated mostly negative).

Question 12 stated, “What is your overall impression of the technical capabilities of the embedded learning hardware platform?” The mean for this question was 1.95, indicating that they held a mostly positive belief related to this statement.

Question 13 asked, “What is your overall impression of learning using the embedded technologies system (training platform and modules)? Did it satisfy your learning needs?” The mean score from the 60 participants was 1.96, indicating that they were mostly positive about using the trainer and its accompanying modules.

The last two questions form the survey sought opinions on using distance learning technologies for technical laboratory teaching/learning. Question 14 stated, “Were you able to learn to use this system through distance learning technologies?” The mean score was 1.91, indicating the learners were capable and positive about learning microcontroller technology concepts using distance learning methods.

Finally, Question 15 asked, “Do you plan to use distance learning technologies for instruction in the near future? Yes or No”. The mean score to this question was 1.69, indicating that the group was mostly positive about using distance learning technologies to teach technical concepts in the near future. Sixty-nine percent of the 60 participants plan to deliver technical courses using distance learning technologies in the near future.

Establishing an Academic Knowledge Community

The overall goal of this project was to create an academic knowledge community for faculty interested in furthering the knowledge and teaching practices of microcontroller technologies (embedded systems). The research team embraces others interested in teaching microcontrollers to enhance collective thought on these topics. The team wants others to share their knowledge and expertise thought the online Moodle server. The team sees this as an extension to first enhance the knowledge of this teaching community and to use this added expertise to continue the group member’s professional development.

The Moodle dedicated server would be used to share knowledge and support the continuous development of teaching and learning practices about developments within the specialty field of microcontroller embedded technology systems. The knowledge community can provide continuous communication via its listserv for the community and interested groups. In this way, members of the community could share new project ideas and new developments via the community forum. Faculty lessons, laboratory assignments and demonstrations, advanced projects, and chats could be posted. Questions of the unknown for a particular faculty member could be raised and then addressed by other members of the community. Additional professional development teaching lessons could be planned and delivered via the Adobe Connect technologies as new modules are developed by community members. This overall outcome is what the project team envisions as the continuation of explorations in teaching microcontroller embedded systems technologies.

Summary

The use of distance learning technologies can be adapted to the delivery of engineering technical laboratory courses. It is important to analyze the outcomes that one seeks from distance instruction and also to understand time is needed for initial preparation prior to instructional delivery. Identifying a common technical package for delivering instruction and development of supporting materials are important. Methods need to be planned and developed for the storage and access of information and teaching aids that support teaching.

The delivery technology then needs to be identified and training is needed on its use. During instruction, knowledge of learners and their acceptance of distance instructional technology are important. After instruction is initiated, constant updates and modifications will need to be made to achieve the instructional goals one sets for their technical courses.

Advantages of real time (active) distance learning include the simulation of face-to-face laboratory environments. To have this occur, planning and developmental work are required.

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