120th ASEE Annual Conference & Exposition
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June 23-26, 2013

Paper ID #7676

Real-Time Interactive Troubleshooting and Assessment of Distance Lab Projects

Dr. Dale N. Buechler, University of Wisconsin, Platteville

Professor, Department of Electrical Engineering ASEE Mathematics Division 2011 Distinguished Educator and Service Award Wisconsin Teaching Fellow (UW-Platteville) 2009 – 2010 Electrical Engineering Department Assessment Chair (2008 – Present) ASEE Mathematics Division Chair (2006-2007) ASEE Mathematics Division Program Chair (2005-2006)

Dr. Phil J Sealy Jr., University of Wisconsin, Platteville

Dr Sealy studied at UW-Madison where he earned the BS AMEP, MSEE, and PhD EE. He is currently the chair of the Department of Electrical Engineering at UW-Platteville.

Mr. John R Goomey, University of Wisconsin, Platteville

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Abstract

In the fall of 2008, the electrical engineering (EE) program at UW-Platteville was expanded to allow engineering students throughout the state to complete their four-year degree remotely. The lecture portion of these courses has been offered asynchronously using streaming-video (SV) technology to accommodate the schedules of working students completing the program on a part-time basis. Our faculty have been trained in distance education and have utilized web-conferencing software to create office hours for remote students which are essentially equivalent to those provided to local students. All course content is website based.

One of the strengths of our electrical engineering program has been the integration of hands-on lab work into all but one of our courses. In addition, design projects are included in almost all our junior and senior EE coursework. Up until recently, all this distance lab work had been facilitated by laboratory managers who have enabled students to complete their lab work at their nearest two-year university system school. This working student friendly program has been successful and has resulted in steady growth of our distance education program.

With more SV students entering the upper-division courses and with the limited availability of lab managers, our faculty and staff have been moving to a new model for off-campus laboratory support. This paper describes the first phases of the transition of our distance laboratories from being lab-manager centered to a distance environment in which instructors, through the use of technology, can remotely assist students with troubleshooting and provide feedback. This approach also allows for the real-time interactive assessment of student lab work in a manner similar to that which is used on main campus for face-to-face instruction.

Background

In the fall of 2008 University of Wisconsin – Platteville (UW-Platteville), located in southwestern Wisconsin, began offering their undergraduate electrical engineering (EE) program to place-bound students throughout the state. This was accomplished in collaboration with the UW system's network of thirteen two-year universities. The map in Figure 1 shows the distribution of the collaborating campuses. This program has been designed so that students can complete the entire four-year engineering degree locally without having to travel to the UW-Platteville campus. Students complete their prerequisite coursework at their local two-year university and work toward the completion of their Associate's Degree. Concurrently, they begin taking the first electrical engineering courses remotely from our electrical engineering faculty. Upon successful completion of their core engineering prerequisite courses they apply for electrical engineering major status at our university, thus becoming dual enrolled.

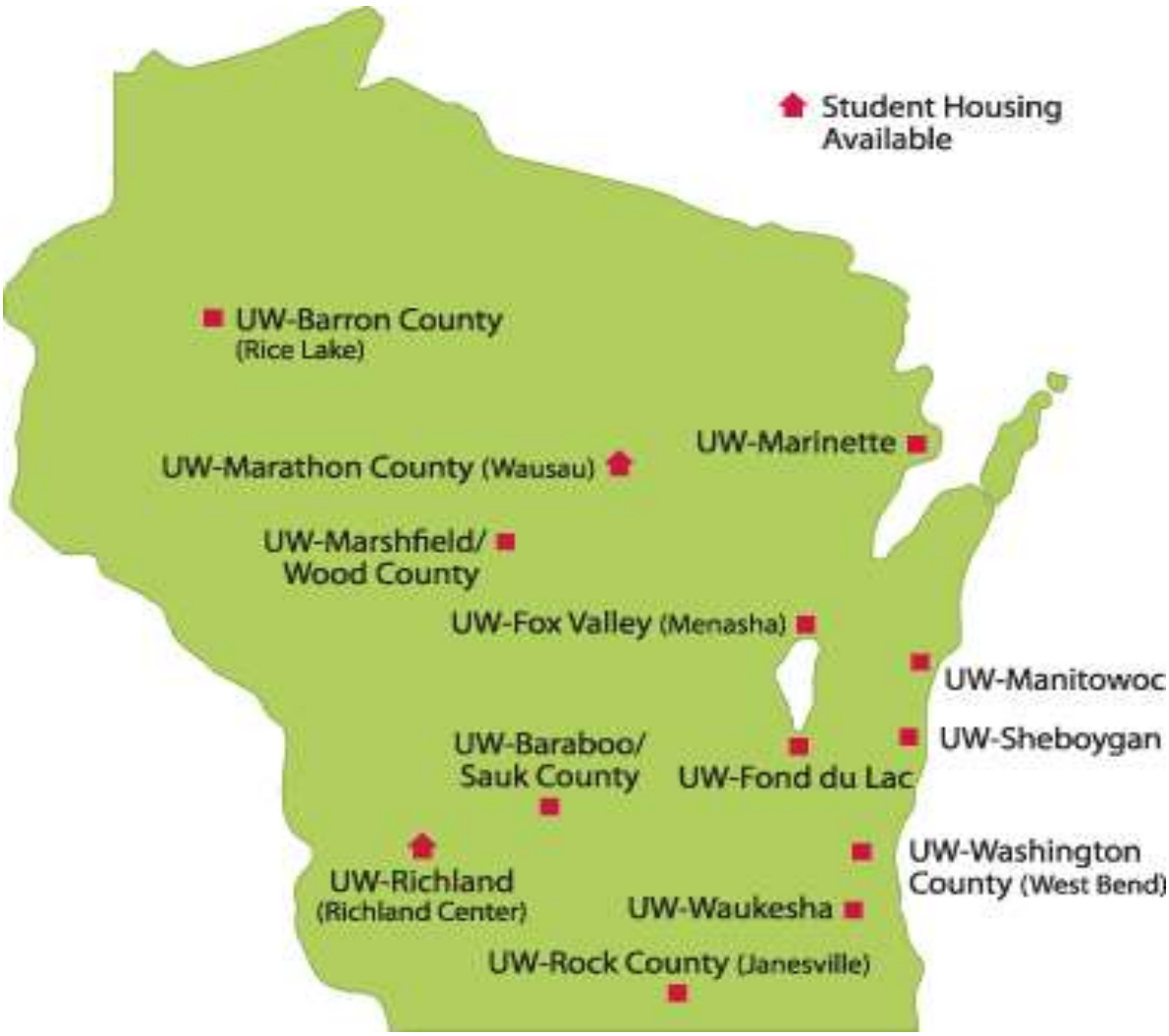

Figure 1. Location of the 13 two-year universities within the UW-System

All EE distance courses are offered using streaming video (SV) technology (asynchronous). This methodology was selected to accommodate the different schedules of students within the program. The streaming video lectures are recorded live while the faculty lecture to the local students and are posted within 20 minutes of the completion of lecture allowing distance students to watch the lecture at their convenience. All course content (syllabus, links to recorded lectures, reading assignments, homework, homework solutions, laboratory projects, examples, web-based resources, etc.) is posted on the course webpage (Desire to Learn (D2L)). All assignments and laboratory reports, for both local and distance students taking the course, are submitted and returned via an electronic dropbox. Grades are uploaded to the course webpage so that students can track their progress.

One of the major issues in the education of distance engineering students is office hours. Most younger engineering students have a difficult time expressing in words the trouble they are having with a specific assignment or concept. To facilitate communication with our distance students, many faculty have been using web-conferencing software, such as Adobe Connect Pro

or Blackboard Collaborate (Elluminate), to allow sharing of whiteboard space, documents, and applications. This software will also allow the instructor to share control of his/her desktop allowing the instructor to oversee application of any program (Spice, Matlab, CAD, etc.) and provide feedback. This communication is enhanced if the technology enables two-way electronic written communication via tablet PCs or pen tablets[1]. More recently web-based discussion forums have been added allowing students to more easily communicate with other students in the course.

On-site lab offerings

Laboratories play a major role in our electrical engineering curriculum. All but one of our EE courses (Electric and Magnetic Fields) have an integrated laboratory component. Faculty teach both the lecture and the laboratory portions of the class (no teaching assistants). We feel that hands-on application of theory is a strong component of good learning. Most of our courses have significant design projects. In our entry level courses, laboratory experiments are used to verify theoretical concepts and to teach the students how to use basic lab equipment. Faculty take an active role in the lab and are always present with the students during the assigned lab times, helping students with lab equipment, teaching circuit layout and soldering, troubleshooting circuits and software, assessing techniques and results, explaining the relationships between classroom theory and laboratory implementation. Assessment of the students' understanding and ability is relatively straight forward in these cookbook experiments. The laboratories in Circuit Modeling II, a transition course, are focused on conceptual understanding and are used to introduce basic design. Simple specifications with single solutions of the two-equation two-unknown variety are common, although we also require a few designs where there are not enough equations and the students must choose components based on other engineering criteria such as cost, availability, sustainability, etc. In higher level courses, lab work is heavily focused on design projects with very few if any cookbook experiments.

In our design classes students are expected to work independently in the lab with scheduled faculty guidance. In many classes the specifications of each student or student group are different (either assigned or related to the digits of a student identification number) so each student or group is working on a related but different design. This is done to minimize the direct copying of designs from other students/groups.

Students typically submit a series of scheduled written or oral reports outlining progress made on a project. Faculty critique the reports or presentations and the student continues the process until the design is completed and demonstrated in the lab to the satisfaction of the faculty and a final report is submitted. Final design checkoffs may take anywhere from ten to twenty minutes depending on the preparation and skill of the student and the complexity of the design.

Many design courses require five to seven such designs. Students will self report anywhere from ten to forty hours invested in design, project management, simulation, reporting, fabrication, and testing while working on a single design lab in one of our design courses. Each student is

required to take at least two of our heavy design courses and most junior or senior courses have at least one large design project. The collaborative engineering program was initially designed for non-traditional students at a couple of two-year campuses in industrial areas. These students take most of their classes face to face with local engineering faculty. The limited number of local faculty cannot be expected to teach every possible elective so some technical electives are offered via distance. Since students are learning the laboratory fundamentals face to face, we thought that offering a few technical electives via distance would be manageable. The distance engineering program has since grown to include all the two-year schools in the state and more recently the collaborative sites with engineering faculty are offering distance courses back to the UW-Platteville campus. Our decision to make the entire EE curriculum available to remote portions of the state via streaming video has given us the opportunity to look at our curriculum and determine how we could offer an equivalent version of our laboratory intensive program to remote students. Faculty searched the literature and internet for distance education models for the laboratory portion of our electrical engineering program. Our search resulted in two model types. Some programs used virtual laboratories combined with cookbook labs and some required students to physically come to the main campus to complete their lab work (either on weekends or in the summer). After some discussion the faculty decided that neither approach could completely fit our students' needs. The former approach may be fine for introductory courses but it is completely unacceptable for a heavy design lab. The latter approach is problematic for our student body. It is not feasible for working students, many with families, to travel across the state to complete their labs in a timely way coincident with the course material. As a result, we decided to take the labs to the student.

Evolution of Distance Lab Logistics and Evaluation

Our collaborative engineering program is a hybrid of asynchronous and synchronous delivery. Face-to-face lectures offered locally to students either on the UW-Platteville campus or at one of the primary collaborative sites located at UW-Fox Valley and UW-Rock County (where we have a few EE faculty) are recorded for students enrolled in the streaming video (SV) section of the course. Lab checkoffs are handled in ways appropriate to the level of the class or the particular design project.

Lab Logistics

The two-year campus sites host on-site laboratories during the semester. Since the students and the lab managers are part of the collaborative agreement, there are no special access, parking, or usage fees of any kind. The students are typically taking classes at the host sites which fulfill the general education and pre-engineering parts of the program requirements, so they are already part of the host sites' systems and the host sites benefit from increased enrollment in their on-site courses. Industry near the host sites benefit from the increased number of well-qualified UW-Platteville BSEE graduates who have ties to the host university area.

Lab managers from UW-Platteville handle all lab logistics at the remote sites. They arrange lab schedules with the students and travel to the two-year campuses at the assigned times. Since they cover locations throughout the state, the two lab managers usually create a biweekly site schedule which both students and faculty can plan around. The current lab managers travel an average of four days each week and spend a whole day at one site or a half day at two sites each day. They work with engineering faculty to ensure that the remote students have a lab experience equivalent to those on main campus. One lab manager is based out of main campus, while the other lab manager resides at UW-Washington County across the state.

The lab managers reserve rooms at the two-year campuses for lab usage. They transport and set-up equipment needed for a particular lab and verify operation prior to the arrival of the students. For most courses the lab manager transports a typical assortment of bench equipment such as a power supply, signal generator, and oscilloscope. For more specialized courses the equipment list might include logic analyzers, spectrum analyzers, network analyzers, power systems trainer modules, power electronics or motor drive training modules, inverted pendulums, or whatever else the course requires. At locations where there are a significant number of students the host site may have a space where the lab manager will leave equipment that is most relevant to the courses being taken by the students. The total amount of equipment used in remote sites is roughly half of that on main campus. The two collaborative sites with EE faculty each have 8 complete lab benches with standard lab equipment (computer, power supply, signal generator, and oscilloscope) and one set of the equipment needed for the more specialized courses. At the beginning of the semester, standard lab equipment is placed at each two-year site where EE labs will be conducted during a given semester depending upon enrollment. Other specialized equipment is shuttled between the sites on a rotating basis (one set shared between the 11 two-year schools without EE faculty).

For the first course (this can be faculty dependent) the lab manager will also bring parts for cookbook labs such as resistors, capacitors, diodes, and op amps. We also supply this type of material to our local students in their first class. When the students reach the sophomore level classes where the labs begin to be more design oriented we require them to purchase their own parts just as we do at Platteville. Some specialty equipment like microprocessor-based development boards are provided to each student in every class where they are used regardless of location.

Each campus has their own computers that the students have access to and virtually every student owns a laptop so we have implemented an online virtual desktop so that students can have access to any of our licensed software at any location where they have internet access. The virtual desktop has been so successful in the collaborative program that we are expanding it to all the students in our entire program Fall 2013.

Evaluation of distance student lab projects

As with most new programs, the streaming-video-only program began gradually. The initial cohorts of SV students began with the low -level courses and have been steadily moving through the core offerings. As a result, we have been allowed to develop the lab curriculum for streaming video a few courses at a time instead of all at once.

For entry-level courses such as Circuit Modeling I, traveling support staff can be used to assess proper usage of lab equipment and to evaluate the construction and performance of simple circuits. The lab managers serve as a resource during the completion of the laboratories at these regional sites. All of the lab assistants are either BS EE or BS ME so in our lower-level classes the lab assistant can do the checkoffs where eyes, ears, mouths, and fingers are required.

As the beginning distance students entered their mid- and upper-level course work which includes design, we had to develop methods to remotely assist students and to assess their work in a manner that was consistent with the ones used to assess our local students. Due to the relatively small number of SV students per class at that time, faculty were able to try different approaches to facilitate distance student learning. The selected assessment techniques used in the lab depended upon the level of the course and were consistent with those used in our face-to-face offerings[2].

Initially two approaches were tested to remotely assess mid- to upper-level coursework. The first is an asynchronous approach in which the lab manager has been instructed to make sure that students have obtained all the required data prior to leaving the lab. Once remote students have compiled all their lab results in the form of tables and figures, they arrange a checkoff via web-conferencing software with their instructor (including both audio and video). During this checkoff, the faculty member can assess that specifications have been met and that the student has a good grasp on the material prior to writing their lab report. This approach requires that the lab manager and the student are both comfortable with the lab and is best accomplished when the student has received feedback, such as a graded prelab or a checklist of required data, prior to entering the lab. One of the main drawbacks of this method is that if the student failed to properly complete a portion of the lab or if they simply failed to document a portion of the lab, they will have to wait until the next time the lab manager is on site again to complete the lab. On the main campus or in one of the collaborative sites where we have faculty it is simple for a student to return to the lab after being redirected by a faculty member and quickly rewire a circuit, retake data, or clear up a misconception. Since the distance students do not always have access to the lab or equipment, it is not always so simple for them to correct something after the the asynchronous checkoff.

A second method, a synchronous approach to lab checkoffs, can eliminate this problem. The lab manager is still there facilitating, but now the student and faculty member simultaneously log into a web conference (and sometimes a phone conference). Cameras, speakers, and

microphones become the eyes, the voices, and the ears of the faculty member while he/she checks specification compliance. The student or the lab manager follows the instruction of the faculty member and points the camera where directed. The faculty member is then able to visually evaluate all aspects of the design.

The faculty member sees live video of the test instrument interface that the student is using in real time and observes the skill with which the student operates the test equipment. The student can answer (or ask) questions just like in the face-to-face labs on the main campus. Faculty can provide immediate feedback on progress and assist in troubleshooting equipment or circuits. Thus the distance students often get more direct faculty help in the lab than their main-campus counterparts who might ask for help from a willing older student hanging around the lab. In this way the distance students become comfortable with the lab equipment and good lab procedure early on and we minimize the number of lab manager visits to each campus.

Through these initial tests we had proven that remote assessment was possible. This approach totally hinged on the availability of a properly trained lab manager on site. But what if such a lab manager was unavailable? What if the lab manager never took the course that they are assigned to facilitate labs for? Scheduling issues, adverse weather conditions, or equipment problems can and often do alter the best laid plans of faculty for their courses. As stated above we have two lab managers, however, this year the most senior of the lab managers went on active duty in Afghanistan. The university was unable to produce a trained replacement in his absence. Therefore, as faculty, we were forced to look at contingency plans for the coming year.

Timing for Labs that require a lab manager had to revolve around the travel schedule for the remaining lab manager which had become quite regimented due to the demands of a growing distance program. However, not all of the upper-level labs require the presence of a lab manager. By the time EE students get into their junior year they are quite familiar with the operation of standard lab equipment and as long as they have access to the lab equipment they can complete most labs without the assistance of the lab manager. The check-off for higher-level non-design labs or simulation-related design labs can be handled by faculty and student alone via web conferencing software during scheduled office hours for remote students. This allows faculty to have more freedom in the timing of some of their lab projects.

In addition, many of the heavy-design courses require more than the weekly allotted time provided by the lab manager to complete. In these cases, the lab managers have arranged temporary space at the two-year school to leave equipment for student use. Some students bypass this process and use equipment at their workplace afterhours, or use equipment that they own to do the labs. Student lab questions are handled by faculty during their designated office hours via web-conferencing software. This approach is similar for students who are taking the course locally and are seeking assistance during office hours. Check-offs can also be handled via distance using a combination of web-conferencing software (audio and video) and cameras focused on the student's work and test equipment. While this is not optimal (better to have a lab

manager present), our multi-stage design process (prelab, separate lab specs, check-offs with professors to verify project understanding, and written lab reports) used at UW-Platteville to verify a student is doing their own work tends to work quite well for assessing the work of distance students.

With the growth of these distance programs constant communication between UW-Platteville and the UW-System two-year schools (UW-Colleges) is essential. Part of the difficulty is that although the UW-Colleges are part of the same university system they are a separate institution. A two-day meeting was held in January 2013, where faculty representatives from each of the UW-College locations and UW-Platteville came together to discuss logistical issues. As of the beginning of the fall semester 2013, all but one of the sites had designated space set aside to house a set of basic lab equipment (power supply, oscilloscope, signal generator, computer, and web cam). We are in the process of negotiating expanded (after hour) access for students to this equipment since many of our distance students are non-traditional students and work during the day. To facilitate distance troubleshooting, last summer we purchased several pieces of test equipment that include LAN connections including the oscilloscope shown in figure 2.

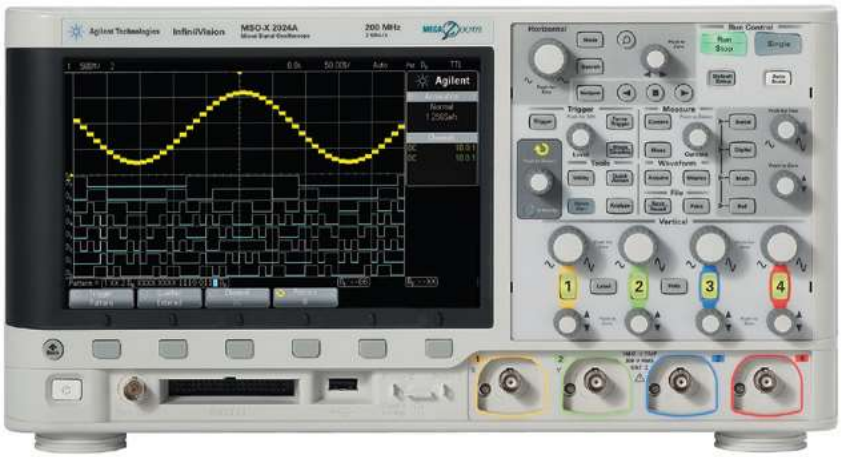

Figure 2. Agilent Oscilloscope with LAN Module for remote troubleshooting

This equipment would facilitate engineering student access in-between lab manager visits and facilitate remote troubleshooting and assessment of upper-level student projects by faculty. It was tested this past summer and was scheduled to be put in service at a few remote sites in fall 2012. Unfortunately the implementation was held up by the logistical issues which were finally overcome in the January meeting.

Program Growth and Recent Accreditation Visit

In 2010 the EE program offered 10 sections of streaming video classes with an average of 3.1 distance students per section. By 2012 that number had risen to 13 sections with an average of 8 distance students per section. During the period from 2010 to 2012 the three co-authors offered

10 streaming video lab courses with an average of 5.8 distance students per class. The number of local students in the sample is 169 and the number of SV students in the sample is 58. The results are combined from several classes and show a higher lab grade and final grade among the distance students when compared to the students taking the face-to-face version of the class. The average lab percentage and the average overall course percentage for the SV students were 87% and 81% as compared to the local students who got 81% and 76%. That's a half grade higher in the lab and a half grade higher in the overall class.

The distance EE program was evaluated for the first time as part of the accreditation visit which occurred in the fall of 2012. Since this program is an extension of the EE program at UW-Platteville, we were required to document that the distance offerings of our courses including the labs offered the same educational experience and accomplished the same educational outcomes as the local main-campus offerings. In the preliminary report, not only did the distance program meet this requirement, but it was also considered a strength of the program by the accrediting body.

Conclusion and next steps

The students in our distance program live up to our standards at least as well as the local students. We do not claim that the entire reason for their success is our distance lab practices although we have put a considerable amount of time and effort into improving them.[1,2,3,4] This may seem to many like an inefficient way to handle the lab portion of the program. Not every program has the dedicated faculty who are willing to do what we are doing, but it has yielded students with skills in high demand. In the last five years, we have had a 90% placement of our students by the time of graduation with a 100% placement within six months.

We know that the number of students in our distance program will be growing at a faster rate than the number of students on the main campus. Soon it will be common to have a quarter or more of the students in any class taking it from a distance. As distance students become a regular part of what we do we are always looking for ways to improve the efficiency of our distance offerings. We are currently negotiating with the two-year schools to gain dedicated lab benches in the spaces they have recently provided with expanded access at each campus and specialized equipment at regional sites. Depending upon the results of these negotiations and associated university funding, the role of the lab managers will likely change. The lab managers will continue to play a major role in the logistics of all the distance lab offerings and will continue to have an essential role in the lower-level courses' distance lab offerings and labs that utilize specialized equipment. As the distance student population grows and more students get to the upper-level classes, faculty will have to develop more efficient distance lab practices to accommodate more students. This will include implantation of modern communication technology such as LAN enabled test equipment and dedicated audio-visual systems at each site to help the students interact with the faculty

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