A Unique Web Environment for a Remotely Accessed Laboratory

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Abstract

Web-based learning is a hot topic; both online courses and remotely accessible laboratories are widespread. Implementation of various course management systems and other distance learning resources has become common for online courses. Similarly, many new approaches to web-enabled data acquisition have been developed for online laboratory experiments. This paper describes a new online framework for laboratory experiments that combines existing elements of online courses and laboratories. The web environment integrates the instructional design and assessment capabilities of WebCT Vista™ with real-time remote monitoring and control of energy equipment, resulting in a unique online laboratory package. The framework supports multiple lab experiments in which Mechanical Engineering Technology students throughout Indiana analyze energy equipment that is physically located on the West Lafayette campus of Purdue University. The paper includes feedback on the web environment from its deployment in the Fall 2004 and Spring 2005 semesters.

Remote Laboratories Background

The Mechanical Engineering Technology (MET) program at Purdue University offers associate degree programs at seven different locations throughout the state of Indiana. Common learning objectives for MET courses are used at all locations to ensure consistency, but laboratory facilities vary significantly between locations. The main West Lafayette campus has enough enrollment and resources to support laboratory facilities that are more sophisticated and extensive than those at the six other smaller locations. Providing online access to this modern equipment would allow an improved educational experience in locations where funds are not available to duplicate the equipment and experiments used in West Lafayette.

Students in West Lafayette have been using two commercially available web-enabled control systems for several semesters to monitor existing solar energy and building automation equipment. A more recent version of one of these systems is the WebLite™ software by KMC Controls, Inc. A typical WebLite™ controls interface is shown in Figure 1, which students use to access real-time data from the solar energy equipment in West Lafayette. It was desired to make these web-enabled control systems available to students for energy laboratory experiments at all MET locations throughout Indiana. Since the summer of 2003, considerable work has been completed to update the control systems and their user interfaces, to design a website for information about and access to the systems, and to develop an interactive web environment containing all of the instructional design, real-time data acquisition, and assessment components of the remote laboratories.

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Figure 1. One web-enabled control system used for monitoring solar energy systems.

The focus of this paper is the unique online framework used for these remotely accessed laboratories, which bridges the gap between existing distance learning solutions. The concepts for web-based learning have been studied and re-examined[1,2,5], but little attention has been placed on web-based laboratory experiments. The feasibility of real-time laboratory experimentation has been proven, but the focus was on system requirements rather than an effective pedagogical laboratory environment[4].

Architecture of the Remote Access Laboratory

Structure and Functionality

The remote laboratory architecture consists of three web-based systems: a remote access webpage system, a web-enabled data acquisition system, and an online course management system. Each independent system is stored on a separate server at different locations around the campus and is managed with unique passwords. The conceptual framework provided in Figure 2 explicitly shows the linkage between the remote access webpage system and the online course management system. The web-based data acquisition system is implicitly included, in the "Lab Experiment" icon within the online course management system.

The "Remote Access Webpage System", shown in the upper part of Figure 2, is housed on a standard web server in Purdue's College of Technology. This serves as the publicly accessible part of the overall environment; no password is required for general access. This system includes general information about the remotely accessible energy laboratory project, a computer

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requirements page, and contact information. It also contains a single introduction page for each remote experiment. Currently solar energy, building controls, and HVAC system experiments are available.

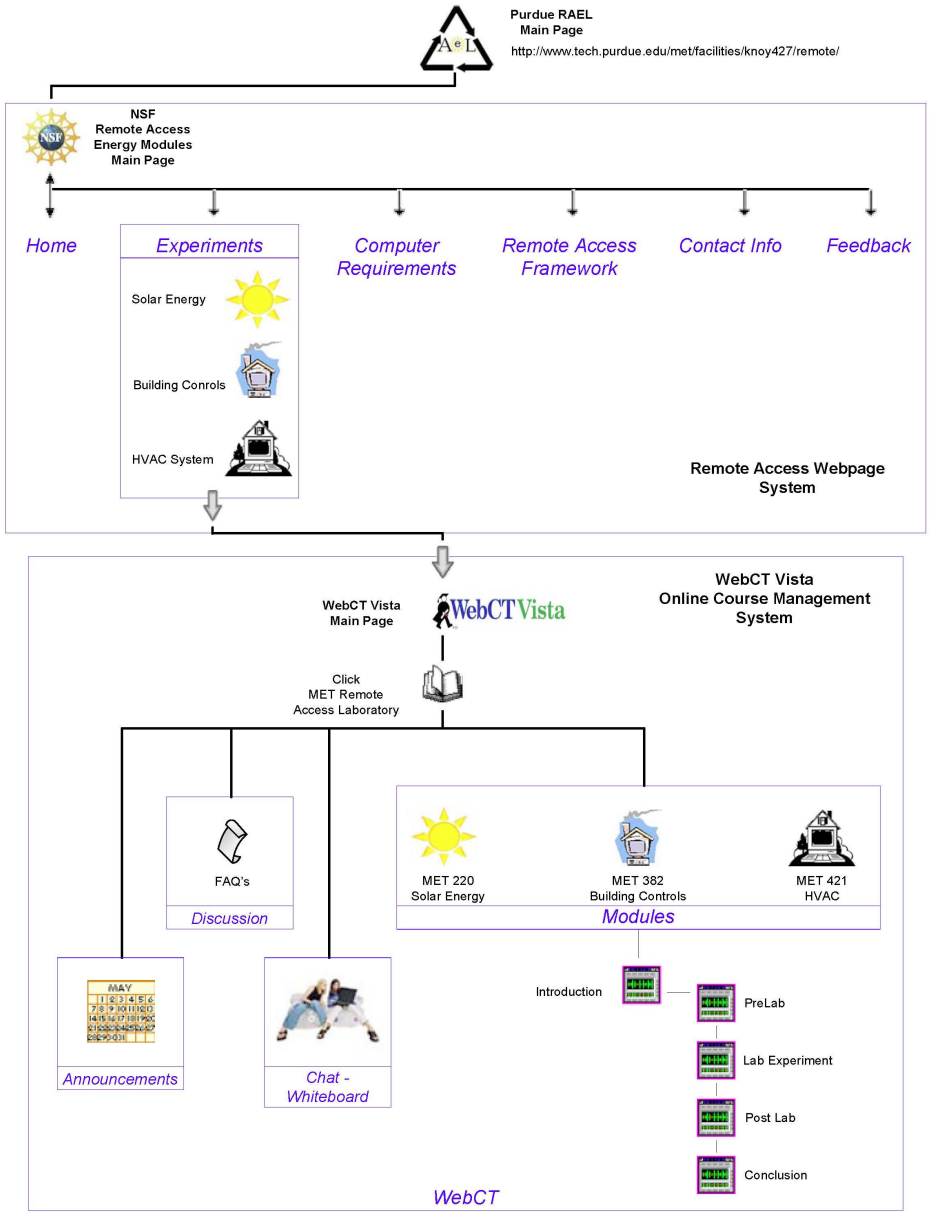

Figure 2. Conceptual framework of the remotely accessible laboratory.

From the introduction page of each experiment on the remote access webpage system, users may access the "WebCT Vista Online Course Management System", shown in the lower part of Figure 2. WebCT Vista™ combines tools for general online course management in any subject area[3]. At Purdue, WebCT Vista™ is housed on a central server managed by the campus-wide information technology staff, and each user must have a unique username and password. For the remotely accessible laboratories, Vista™ provides a password protected web environment for

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instructional content (text, handouts, photos, video tutorials, links to data acquisition, links to reference websites, quizzes, and surveys), student collaboration (FAQs, chat room, whiteboard, and email), as well as administrative functions (course syllabus, course announcements, course calendar, and an automated grade book). Additionally, unlike the HTML formatted pages in the remote access webpage system, WebCT Vista™ allows structured, synchronous access to experiment steps and asynchronous access to all previous experiment steps and related information.

The WebCT Vista™ interface for the remote energy laboratories has been designed to integrate all necessary functions for three separate laboratory experiments. Each laboratory experiment has its own link on the Vista™ home page. Once a student enters a specific experiment, a learning module structure has been implemented to ensure students perform the experiment in a prescribed order. Figure 3 shows the entry page for the solar energy remote experiment. On the left is the table of contents for the learning module, in this case only the steps visible when students first access the experiment are shown. In the frame on the right is a simple HTML webpage introducing the experiment and providing basic instructions for completing the module using the steps in the table of contents.

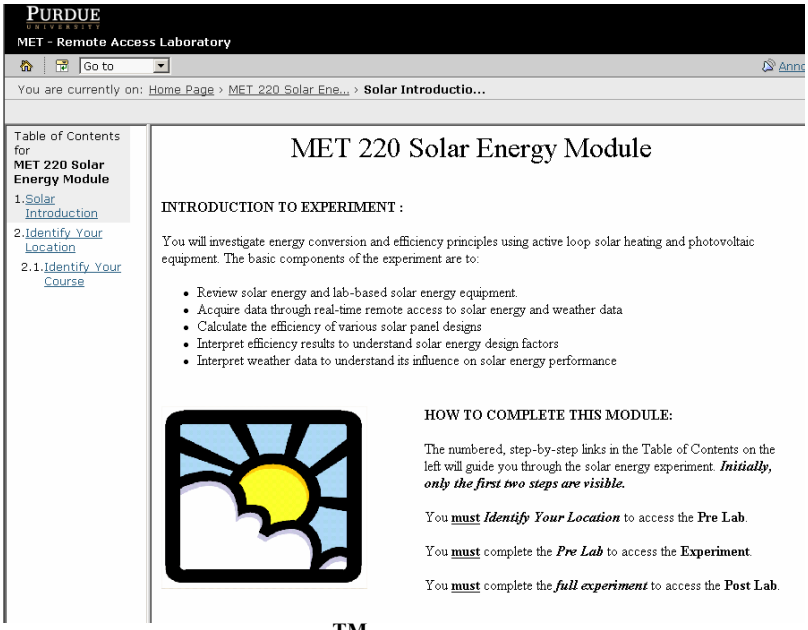

Figure 3. Initial WebCT Vista™ page for the solar energy experiment.

The order in which students complete the experiment elements has been constrained using Vista™'s selective release function, so that valid assessment of the remote labs can be accomplished. The basic goal of the integrated assessment is to demonstrate that student learning has been achieved with these remotely accessed lab experiments. To support this assessment, details of the experimental procedure are not available to the students until they complete a short pre-lab quiz. The post-lab assessment is not available until they have completed the experiment in full, and they must first answer a question about their final experimental results before having access to the post-lab quiz. An example pre-test is shown in Figure 4. Completion of both the pre-test and post-test are required deliverables for the laboratory assignment.

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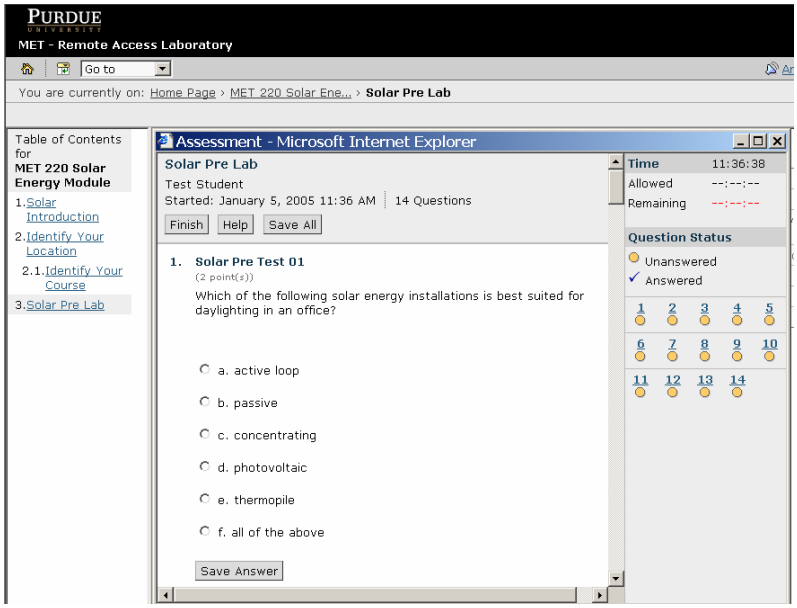

Figure 4. Solar energy pre-lab used for student assessment.

Once students complete the pre-lab assessment, they have access to the full experimental procedure, all supporting documents, and links to the web-enabled control systems for data acquisition. As an example, for the solar energy experiment, the full procedure contains:

- An introduction to types of solar energy systems and the need for solar energy
- A downloadable file containing the data tables needed during the experiment
- Links to a website and local weather camera for up-to-date weather information
- Link to the web-enabled control system for real-time data acquisition (the interface for this particular step is shown in Figure 5)
- Instructions for analysis and discussion to be completed after the laboratory session

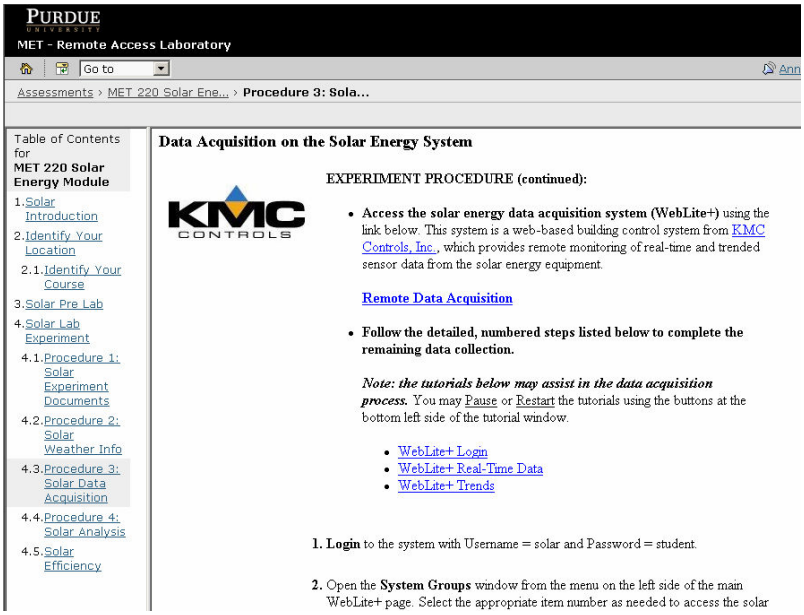

Figure 5. Example of remote lab interface for real-time data acquisition.

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Additional Technical Details

A variety of technical resources were used to create the remote access laboratory architecture. The majority of the individual content and informational pages within both the remote access webpage system and the WebCT Vista™ online course management system were constructed in HTML format using Macromedia Dreamweaver™ software. Selected pages and files, such as the conceptual framework and introductory materials, were converted into Adobe PDF files from MS Office™ and MS Visio™. At least one ASP page collects user feedback comments and initiates an email to relay those comments to the website manager. Several video tutorials, which demonstrate the more complex tasks required throughout the experiments, were created using Qarbon ViewletBuilder4 software (SWF file format).

Within the web-enabled control systems, the data acquisition interfaces were constructed using KMC Controls' WinControl™ software and Automated Logic Corporation's WebCTRL™ software. The data acquisition systems provide a password protected (global username and password for all students using the system) online environment for data collection functions including real-time access to sensor data, graphs, trends, and equipment schematics. These web-enabled control interfaces are accessed through the WebCT Vista™ system side-by-side with the instructional materials and other pages.

The result of all of these HTML, ASP, SWF, data acquisition, and WebCT Vista™ pages is a multimedia, hybrid instructional domain with seamless access across system lines and file formats.

Feedback and Assessment

The web environment described above was used by students at the main West Lafayette campus for the first time in the Fall 2004 semester. Two different laboratory experiments were delivered, one in each of two courses, using the new framework. Although students in West Lafayette could have had access to the physical equipment, they were restricted to completing the laboratory experiments online for assessment purposes.

Only informal feedback (student comments and instructor observation) was obtained on the new web environment in the Fall 2004 semester. Feedback varied across courses. For the solar energy laboratory experiment, feedback was primarily positive. Based on student comments, minor modifications were made in the WebCT Vista™ module to make some of the procedure sequence more obvious for the Spring 2005 semester. For the building controls experiment, which has a similarly structured but not identical interface, the students enjoyed the online data collection, but many didn't see any added benefit by the WebCT Vista™ interface.

To further identify the overall effectiveness of the remote environment, a more formal assessment was implemented in the Spring 2005 semester. Students complete a pre-test and post-test for each experiment. These tests include both objective quiz questions to gauge knowledge acquired as a result of the experiment and survey questions to determine the impact of the experiment and the web interface. Data collection will be completed throughout the Spring 2005 semester.

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For the solar energy experiment, an initial look at the Spring 2005 data highlights some preliminary results. First, the students did not show significant improvement in their post-test scores as compared to their pre-test scores. Although there was an increase in mean score from 12.9/24.0 on the pre-test to 13.6/24.0 on the post-test, further analysis revealed this increase was not statistically significant. The null hypotheses stated the post-test scores were equal to the pre-test scores and the alternative hypotheses stated the post-test scores were greater then the pre-test scores (Ho: U1 = U2, Ha: U1 > U2) on a 95% significance level. From a t-test for the combined pre-test vs. post-test data sets, it was determined that the P-value was equal to 0.1443, suggesting that the slight increase observed was not statistically significant. As partial explanation, a quick review of the objective quiz questions shows that the post-test may have inadvertently been designed at an overall higher level of difficulty than the pre-test.

Additional results were derived from student responses to the survey questions. Figure 6 contains combined results from the pre-test and post-test, highlighting the median survey scores (on a scale of 1-5, where 5 corresponds to strongly agree and 1 corresponds to strongly disagree). Prior to the experiment, shown in the first two survey questions on the left, students believed it was always important to have hands-on access to real equipment for lab experiments. After the experiment, students rated the remote access concept more favorably, and many students were able to see the value of remote access in their future careers. However, students were not certain how the WebCT Vista™ interface enhanced the remote access environment. Long term implementation of the remote environment will likely need to address these concerns.

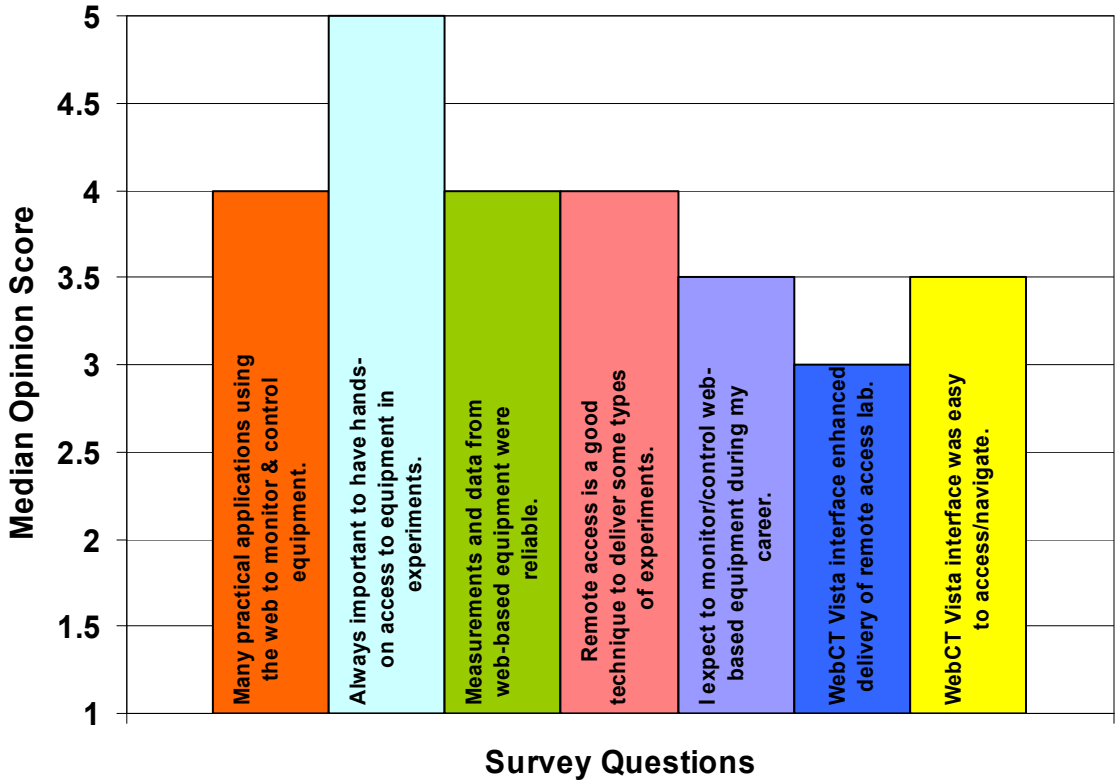

Figure 6. Student survey results for Spring 2005 solar energy experiment.

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Conclusion

An online interface has been successfully developed for delivery of remotely accessed energy laboratory experiments. The remote environment integrates the instructional design and assessment capabilities of WebCT Vista™ with real-time remote monitoring and control of energy equipment, resulting in a unique web-based laboratory package. Preliminary results were not conclusive with respect to improved student learning as a result of the remote lab experiments, yet survey responses indicated increased student recognition of the capability for accessing equipment remotely rather than through hands-on experiments. Further analysis of Spring 2005 data is in progress.

Acknowledgment

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Biography

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