Design of a user knowledge-based interface for a remote access engineering laboratory

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ABSTRACT: In this article, the authors present the preliminary results of their ongoing research on the design of a remotely accessible engineering laboratory. In phase I of their project, they designed an engineering laboratory that enabled distance learners to access engineering software and laboratory equipment from a remote location. The results were reported in the article entitled *design of a real-time remote-access engineering laboratory using integrated Web service and wireless technology for distance learners*. To ensure the quality of distance education, phase II of this project focuses on the design of a user knowledge-based interface that gauges students' theoretical and pre-laboratory knowledge competences before granting access to remote laboratories. The interface consists of a series of tests and study guides that assess students' capabilities in conducting a laboratory experiment. Access is granted to those students who demonstrate sufficient theoretical and practical knowledge to proceed with the experiment. Otherwise, students are directed to relevant study guides that help them review and refresh course materials and laboratory procedures for certain experiments. This interface acts as a gatekeeper that helps ensure and improve the quality of distance learning.

INTRODUCTION

Recent leaps in technologies have greatly stimulated the growth of distance education. Along with this growth are the concerns about the quality of the distance education provided. These concerns come mainly from the research evidence that distance learning may be impersonal, superficial, misdirected and could potentially disrupt interactions between instructors and students to create danger for a productive learning community [1]. Nevertheless, because of the unique opportunities it provides to its users, distance education has witnessed rapid expansion despite some disadvantages and concerns.

Many scholars and researchers have been working diligently to address the concerns related to distance learning. Cavanaugh presented critical success factors that may lead to high quality distance education experiences. Her research suggests that *Technology-mediated distance education research has matured enough to produce an extensive body of evidence that distance education can be at least as effective as classroom instruction* [2]. Hijazi et al conducted an experiment to determine if existing technology is adequate for the delivery of quality distance education by measuring progress, communication mode and the desire to take another course. Their research results indicate that *taking a distance education course was worthwhile* [3]. In their research report of online course effectiveness, Rovai and Barnum found the following:

> *Only active interaction, operationalised by the number of messages posted by students per week, was a significant predictor of perceived learning. Passive interaction, analogous to listening to but not participating in discussions and operationalised by the number of accesses to the discussion boards of the e-learning system each week, was not significant* [4].

Results concerning theories of distance education, technologies and infrastructures of online learning, online course development, resources for e-learners, and online learning quality have been reported elsewhere [5].

The quality of distance engineering education has seen significant improvements due to interactivity, the virtual classroom environment and other new technologies that have been introduced to distance education, such as online discussion rooms, live audio and video streaming. The authors' contributions to distance education quality improvements include their recent research on designing a remote access laboratory using integrated Web services and wireless technology. This design has eliminated the need to transport bulky equipment to a remote location and provides simple, cost-effective and user-friendly accessibility to distance learners to gain real-time hands-on laboratory experiences [6].

Higher quality in distance learning is a product of creative instructional methodologies, enabling technologies and the motivation of students. Highly motivated students generally achieve better learning outcomes. In order to keep students motivated, it is imperative to continuously assess students' knowledge levels and develop apparatus that guide students to master essentials at each learning step.

Phase II of the authors' remote-access laboratory design focuses on students' knowledge assessment prior to their laboratory experiments. Students are only granted access to their desired laboratories after passing theoretical and laboratory skills tests. Otherwise, they are directed to relevant review materials to augment their theoretical and pre-laboratory knowledge. In doing so, it is expected that the quality of laboratory experiments will be greatly enhanced. The following sections report some preliminary results including design concept and design examples.

KNOWLEDGE-BASED INTERFACE DESIGN CONCEPT

The authors' phase II design is primarily a user knowledge-based interface that gauges students' theoretical and pre-laboratory knowledge competences before granting access to remote laboratories. The interface consists of a series of tests and study guides, which assess students' capabilities to conduct a laboratory experiment. Access is granted to those students who demonstrate sufficient theoretical and practical knowledge to proceed with the experiment. Otherwise, students are directed to relevant study guides that help them review and refresh course materials and laboratory procedures for certain experiments. This interface acts as a gatekeeper that helps to ensure and improve the quality of distance learning. A flowchart that demonstrates this design concept is shown in Figure 1.

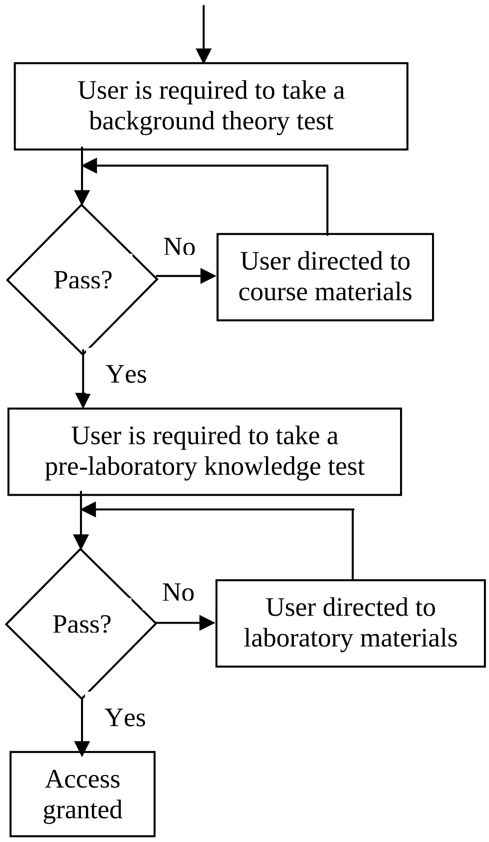

Figure 1: The user knowledge-based interface design concept.

A remote user initiates a session by requesting access to a laboratory experiment. The request is initiated through the instructor's course Web site. The user is directed to an online test page and is required to take a background theory test related to the laboratory experiment requested. The purpose of this test is to assess the student's understanding of course materials that lies behind the requested laboratory. The questions are designed to make sure that the student understands the theory of operation of a certain laboratory. If the student does not pass the test, he/she is then directed to the relevant course materials to review the theories learnt in class and is required to take another test before proceeding to the next step.

Once the student has passed the background theory test, he/she proceeds to the next step to take a pre-laboratory knowledge test. This test emphasises those skills needed to successfully complete the laboratory experiment. If he/she fails the test, then he/she is directed to relevant pre-laboratory materials, such as laboratory notes or the equipment vendor's educational site to prepare for the laboratory.

Upon successful completion of both tests, the student is granted access to the requested laboratory.

The questions in the tests are multiple choices for easy Web grading. Test data banks have been built for each experiment. Questions are randomly picked out from the data bank each time a new test is generated. This can be accomplished using *ExamView Pro*, a test generation software package by FSCreations Inc. Interested readers can find more information about this package at www.examview.com.

At the current design stage, the test results are displayed for students to view after taking the test and sent to the instructor via e-mail at the same time. The instructor (or graduate assistant) grants permission to students based on the test results. This helps the instructor obtain data for monitoring the effectiveness of this method. In the future, this process can be automated by real-time password generation and remote users can gain instant access to the laboratories if they pass the tests.

In ref. [6], two laboratory exercise examples were given for the purpose of verifying and demonstrating the feasibility of the real-time remote-access design concept. It is natural to use the same two examples to illustrate the user knowledge-based interface design. The following is a reiteration of the two standard laboratory exercises found in ref. [6].

The first of two laboratory exercises used was the *PLC control of an alarm system*, in which students are introduced to PLC ladder logic programming using the Siemens 224 series PLC and its related software, *MicroWin*. Students are introduced to PLC ladder logic programming, which covers ladder logic, editing rungs and simulating circuits. These skills enable students to develop a control program for an alarm system using standard functions, such as basic inputs, outputs, latches and timers. A simulated control of the system has been implemented at the Automation Laboratory at Western Carolina University (WCU), Cullowhee, USA, allowing students to verify their program execution by downloading their developed program to a pre-wired Siemens S7-224 programmable logic controller (PLC) enabling the manipulation of the alarm system work station.

The second laboratory exercise used was *PLC control of a measuring system* in which the student is required to control an X-Y positioning table and sensor to measure the width of a part. The movement of the table is controlled by a stepper motor that, in turn, is controlled by his/her ladder logic program. Once the program is developed, it will be transferred to a Siemens S7-224 programmable controller for simulation.

The ladder logic for each laboratory experiment requires a few minor changes from the conventional format so as to facilitate the remote control of the PLC. For example, a remote user does not have the capability to physically control any physical inputs, such as a system *START* button or a system *OFF* button. Therefore, a technique known as *forcing a bit* was employed to address this issue. This technique consists of entering the relevant bit's address into the *MicroWin*'s status chart feature and entering a one for *START* or zero for *OFF*. This modification gives remote users complete control of operating an experiment station at any time.

In the next section, the authors discuss the interface design and the test examples corresponding to the above laboratory exercises.

DESIGNED INTERFACE AND EXAMPLE RESULTS

Figure 2 shows the background theory test for laboratory 1. The interface collects student's information, including name, ID and e-mail. The same information will be sent to the instruction when the student submits his/her test. This test is aimed at assessing the student's understanding of concepts to conduct laboratory 1, including scan cycle, real world inputs, latched condition, PLC TON timer and SET function.

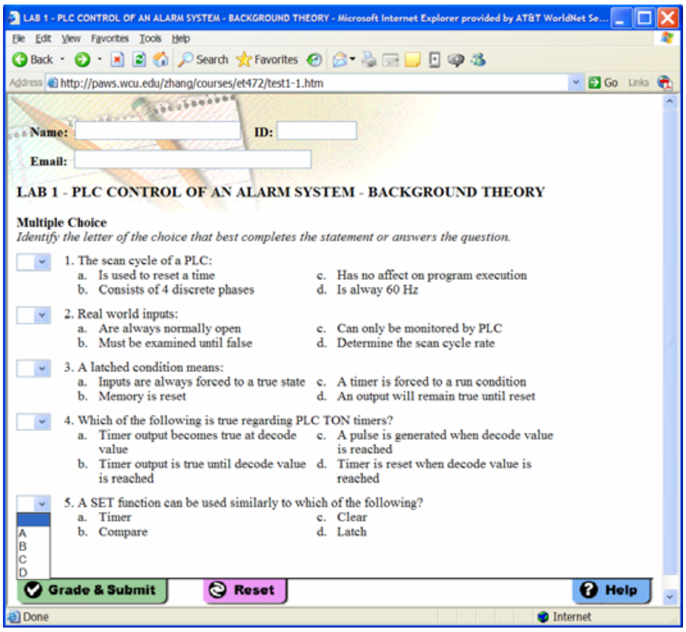

Figure 2: Background theory test for Laboratory 1.

Figure 3 illustrates the student's view of the test result. The student view only tells the number of correct answers and the percentage of correctness without giving details of the answers. This encourages students who did not do well on the test to carefully review materials before taking the test again, instead of guessing the answers to try to pass.

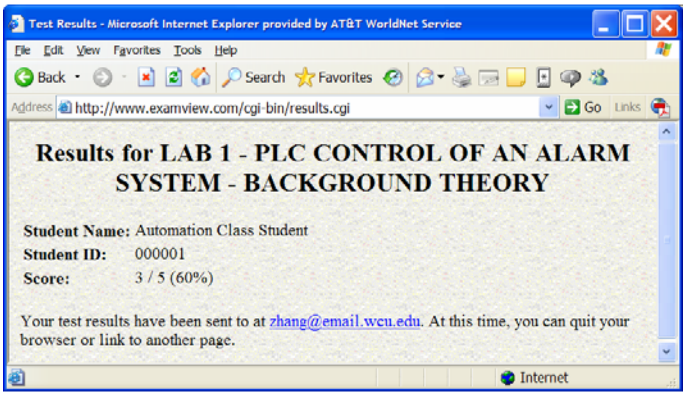

Figure 3: Student's view of the test result.

Figure 4 presents the instructor's view of the test result. This result gives details on the correct and incorrect answers that the student provided. This information is helpful to instructors in two ways: it helps the instructor refine the test questions by removing any ambiguities in the questions, and it helps instructors assess students' weaknesses.

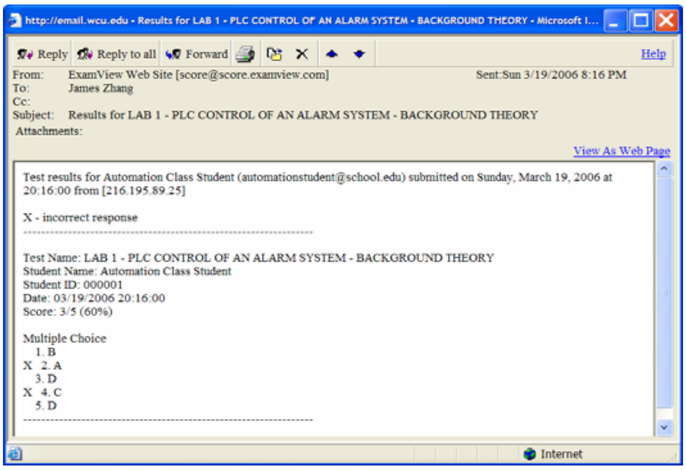

Figure 4: Instructor's view of the test result for laboratory 1.

Figure 5 is the pre-laboratory knowledge test associated with laboratory 1. This test emphasises students' technical skills when successfully conducting laboratory 1. The skills tested include technical specifications and the parameters of programming, as well as setting up laboratory equipment.

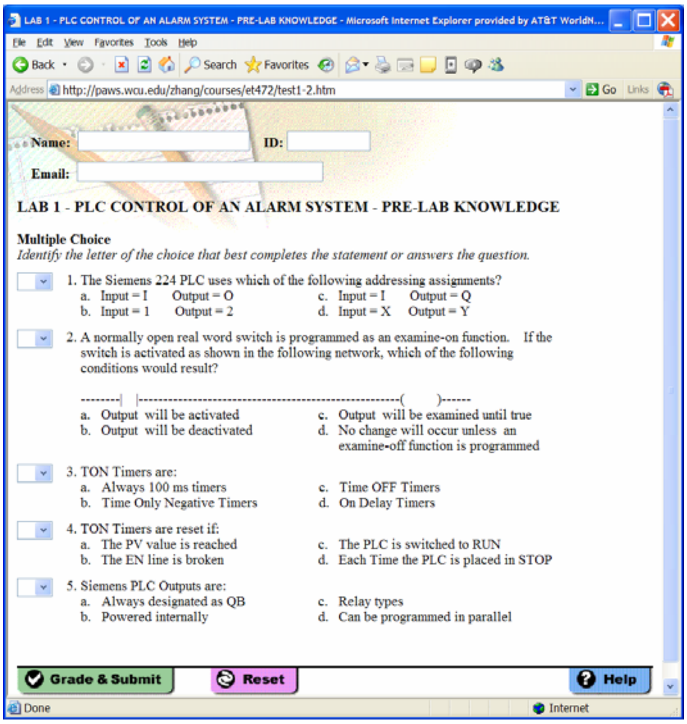

Figure 5: Pre-laboratory knowledge test for laboratory 1.

The format of the tests for laboratory 2 is similar to that of laboratory 1. The background theory test and pre-laboratory knowledge test questions are listed in Tables 1 and 2, respectively.

CONCLUSIONS AND FUTURE WORK

The user knowledge-based interface design for a remote-access engineering laboratory has helped to improve distance education quality by assessing students' theoretical and practical knowledge prior to conducting a laboratory exercise. Requiring students take two tests encourages students to review and enhance their knowledge gained from instructional sessions. The records of test results have also helped instructors to identify students' weaknesses and, therefore, improve instructional quality.

Table 1: Laboratory 2 background theory test.

1. The Positive Edge Transition (PET) provides which of the following?

a. One positive pulse for every counter increment	c. One positive pulse for every timer output
b. One positive pulse for one scan cycle	d. Continuous positive pulses in a serial pulse train

2. The position of a stepper motor is controlled by:

a. The number of pulses	c. The time interval between pulses
b. The frequency of pulses	d. The pulse width

3. A bit pattern sequence is used to control stepper motors. Which of the follow is true?

a. A unique pattern is required for each pulse	c. The same bit pattern is used for forward and reverse
b. The bit pattern is random and referenced in a data table	d. A different bit pattern is required for forward and reverse

4. MOVE_B functions can be used to:

a. Transfer data words from a data table to the output register	c. Control bit pattern sequences
b. Multiply constants for calculating step angles	d. Calculate the frequency of pulses in a pulse train

5. MULTIPLY functions in the Siemens 224 require which of the following?

a. Byte	c. Bit
b. Word	d. Double word

Complete automation of this remote-access laboratory design will allow students to consolidate their knowledge and conduct laboratory experiments from anywhere at anytime. The successful implementation of this project will also have a broader impact on on-campus students as well. On-campus students can also take advantage of this design to enrich their learning experiences.

The authors will continue to work on the project in order to solve some minor issues associated with implementation. The authors' future work will focus on the assessment of the effectiveness and improved quality of this approach. One graduate assistant will be allocated to help with assessment activities and the results will be reported when sufficient data have been collected.

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Table 2: Laboratory 2 pre-laboratory knowledge test.

1. The lead screw on the measuring station has a pitch of:

a. 20 TPI	c. $^{1}/_{20}$ inches
b. 0.1 inches	d. 10 inches

2. The theoretical positional accuracy of the X and Y axis is:

a. 0.01 inches	c. 0.0001 inches
b. 0.001 inches	d. 0.0005 inches

3. Mechanical accuracy is determined by:

a. Pitch and step angle	c. Time delay between pulses
b. Frequency and bit pattern	d. Number of PET per scan cycle

4. A preferred method of controlling outputs can be obtained by moving bit pattern sequence data to which of the following types of memory?

a. S Memory	c. V Memory
b. M Memory	d. D Memory

5. Function Keys for the TD200 text display units?

a. Reset a memory bit when depressed	c. Are controlled by MB0
b. Reset a timer when depressed	d. Cannot be used as inputs for control

REFERENCES

1. Nissenbaum, H. and Walker, D., A grounded approach to social and ethical concerns about technology and education. *J. of Educational Computing Research*, 19, **4**, 411-432 (1998).
2. Cavanaugh, C., *Distance Education Quality: Success Factors for Resources, Practices and Results*. In: Distance Education Quality. Hershey: Idea Group Publishing, 173-191 (2002), http://www.unf.edu/~ccavanau/11Cavanaugh.pdf
3. Hijazi, S., Bernard, P., Plaisent, M. and Maguiraga, L., Interactive technology impact on quality distance education. *Electronic J. of e-Learning*, 1, **1**, 35-44 (2003), http://www.ejel.org/volume-1-issue-1/issue1-art5-hajazi.pdf
4. Rovai, A.P. and Barnum, K.T., On-line course effectiveness: an analysis of student interactions and perceptions of learning. *J. of Distance Educ.*, 18, **1**, 57-73 (2003).
5. Anderson T. and Elloumi F. (Eds), *Theory and Practice of Online Learning*. Athabasca: Athabasca University (2004), http://cde.athabascau.ca/online_book/index.html
6. Zhang, J.Z., Ball, A.K., Clare, M. and Extine, W., Design of a real-time remote-access engineering laboratory using integrated Web service and wireless technology for distance learners. *World Trans. on Engng. and Technology Educ.*, 4, **2**, 231-234 (2005).