NSF Final Report
Virtual Experiential Laboratory Exercises
Project # 0101725

1. Participants

   a. People
      i. Doyle Meyer — Principal Investigator
      ii. Michael Lesiecki — Co-Principal Investigator
      iii. Joseph Matoon — Instructional Designer
      iv. Sam Bachert — Graphical Designer
      v. Charles Woodall — Programmer
      vi. Ray Francis — Audio Specialist

   b. Organizations

      i. Maricopa Advanced Technology Education Center (MATEC)
      ii. Partner's Contribution to the Project
         1. Collaborative Research
         2. Personnel Exchanges
      iii. Detail on Partner Contribution
      San Juan College is partnering with Maricopa Advanced Technology Education Center (MATEC) on this project.

      Mike Lesiecki is Co-PI and responsible for oversight of MATEC's participation in the project.
      Joe Matoon acted as an instructional design consultant. He assisted in modifying the competency based distance-learning model developed by MATEC and in the development of the template used for this project.

   c. Collaborators

      An advisory committee representing a majority of technology employers in the San Juan Basin was involved in developing the original project concept and twice provided formative evaluations of the in process work. This committee will also have significant responsibility during beta testing. The Controls Technology and Computer Science departments also participated in the alpha test.

2. Activities and Findings

   a. Project Activities
   <u>Goals and Objectives</u>
   The primary objective of this project was to create virtual laboratory exercises using a model developed by MATEC for Web-based

Controls and Manufacturing Technology classes. These experiential modules are the virtual equivalents of the traditional laboratory exercises of a site-based technology curriculum.

Year One Goal

Develop eight Virtual Laboratory Exercises for an Introduction to Programmable Logic Control (PLC) class. This class enables users to write PLC programs using bit and combination logic, counters, timers and sequencers and to test the functionality of the programs by downloading the programs to a virtual PLC networked to an interactive process simulation.

Year Two Goal

Develop eight Virtual Laboratory Exercises for an Introduction to Process Measurement class. This class enables users to make raw pressure, level, flow, and temperature measurements and then to calibrate industry standard transmitters that convert the raw measurements into the electrical signals computerized controllers use to monitor and control a process.

Overview

The virtual lab exercises provide an environment in which the users can perform laboratory exercises with process simulations that respond to user actions. The simulations look and act like typical industrial processes and provide feedback when users do not perform as expected. The feedback takes the form of statements about expected results with possible causes for discrepancies and clues enabling the user to successfully complete the exercise. The exercises assess student competencies and report student progress to the class instructors.

The rapid growth of web-based education has created a need for a revised methodology in educational curriculum and delivery. This project addresses the crucial experiential component for the education of technicians. Hands-on laboratory exercises traditionally ensure that the learner is able to transfer theoretical knowledge into practical application. We believe this hands-on laboratory experience is critical to the development of a quality site-based program. If we are to effectively educate a technician through distance education, we need to re-create these experiential curriculum components for an intra/internet curriculum. Without this experiential component, education for technicians will continue to be partially to totally site-based.

We believe we have developed a successful methodology and model for delivering the experiential educational components of a technology curriculum and that this model has broad applicability for any technical discipline.

Major achievements and progress to date

In year one of a two-year project, we developed the Virtual Laboratory Exercises for an Introduction to Programmable Logic Control (PLC) class. The class teaches technicians how to program PLC's.

In year two we completed the virtual laboratory exercises for an Introduction to Process Measurement class. This class enables users to make raw pressure, level, flow, and temperature measurements and then to calibrate industry standard transmitters that convert the raw measurements into the electrical signals computerized controllers use to monitor and control a process.

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Processes used in materials development including alpha testing, field testing, and validation by industry

The concept was first presented to the advisory committee of the Controls and Manufacturing Technology Department of San Juan College. The committee also reviewed the first working prototypes. This group has also participated in the alpha test and approved the list of exercises as detailed in the site-based program. The alpha test provided the template from which the rest of the units were developed.

Evaluation instruments were developed to facilitate data gathering both from the perspective of ease of entry for the beta tester and ease of identifying and correcting problems for the developers. Two instruments were developed. (See attached file.) The first is for the alpha or beta tester and facilitates page location and problem identification. The second instrument is for beta testers who are also instructors and addresses broader issues relating to usefulness and appropriateness of the material.

Field-testing will follow the beta test. This test will be conducted with both college and industry representatives. The advisory committee will facilitate the industry participation and be directly involved in beta testing, feedback and modifications made to the project.

<u>Evaluation activities</u>
Evaluation activities up to this point have been primarily formative. The advisory committee provided baseline information about the expected shortage of process technicians and the type of training required. They also provided feedback after evaluating the prototypes. The alpha test provided additional feedback and allowed us to make mid-course corrections before finalizing the template.

We have also demonstrated the project to Cisco, SHAI, Primemedia and Rockwell Software and at several conferences.

b. Project Findings

<u>Major Accomplishments</u>
At the end of year two of a two-year project, we have developed fifteen virtual laboratory exercises for an Introduction to Programmable Logic Control (PLC) class and eleven exercises for an Introduction to Process Measurement class. This total exceeds the proposed total of 16 modules by 10, but were necessary changes to the original proposal based on requirements identified during development. These additions do not represent a change in the scope of the project, but are indicative of changes in the way topics were presented. These two classes teach technicians some of the fundamentals of Process Control and Manufacturing Technology . PLC's are very common computer controllers used in automated processes. Measurement of process variables is the key to accurate process control.

The virtual exercises assess user competencies within simulations that both interact with the user and react to user input in the same way as the physical hardware in a traditional site-based laboratory. The PLC modules provide an environment in which the users are able to write and test PLC programs for the Intro to PLC class. The Measurement modules enable the user to measure process variables and to calibrate process measurement instruments for the Intro to Process Measurement class. These exercises assess student competency in the use of fundamental PLC instructions including combination logic, counters, timers and sequencers for the PLC modules and the concepts and applications of pressure, level, flow and temperature measurement and equipment calibration for the measurement class.

While we have been successful in getting formative evaluations through alpha testing within the San Juan College and MATEC communities and have completed all modules, we have not been successful in completing summative evaluations through beta testing within our local industrial community. Successful beta testing has been limited to internal testing. We have fully completed five beta tests using internal evaluators and have attempted an additional five external testers. We have partial results from the external tests, but have yet to have a single external beta tester complete an evaluation.

The evaluation instruments performed as expected. Some typical problems are listed below.

- A little white box covers part of the text.
- The installation instructions are confusing.
- When I clicked on the Logix button, I got a message that said: failed to update system registry
- Wrong voltage specified for the Fisher transmitter.
- Honeywell SFC not accepting the 4.00 mA current output correction.
- Exit button not working on display
- Would be nice to be able to toggle the Nameplate button.

There are 10 Units with a total of 26 exercises. The units contain introductions written in Macromedia Authorware with the simulations written in Rockwell Software's MMI software package RSView. There are 26 simulations containing 111 displays and approximately 6000 lines of code. We completed 26 introductions to the simulations in Macromedia Authorware with approximately 250 displays and 7200 icons of associated text and illustrations. Contained within the Authorware presentation are approximately 45 Macromedia Flash animations.

Each exercise contains an introduction with a brief review of the associated content, an assessment of content comprehension and instructions for completion of the exercise. The students must pass the assessment activities with a score of 80% or greater to access the next section.

The activity for each exercise is designed to demonstrate specified competencies defined by existing site based laboratory exercises. In each exercise the user performs specific tasks inside realistic simulations of typical petrochemical processes. The simulations have all the functionality of plant processes. The simulations are thus able to interact with the user and test the accuracy of the user responses.

Challenges

The greatest difficulty has been beta testing the modules. A major difficulty in year one occurred after the modules were completed. In late 2002 we upgraded to the latest version of Macromedia Authorware. Just prior to sending the project out to beta testers, we opened the project in the new version of Authorware to make the final changes prior to packaging the modules. Authorware then converted the project to the new version. Unknown to us, there was a significant change in button protocol that resulted in many buttons with broken links that were not discovered until the beta testers began to report being unable to navigate past certain pages of the project. They became discouraged and stopped working on the project and we did not find this out for a couple of weeks. When the problem was identified, we found we could not go back to the previous version. It took three weeks to locate and fix the broken links.

In addition, we have found that the beta test takes approximately 40 to 60 hours to complete and this has resulted in great difficulty in getting beta testers to complete. We are investigating the possibility of offering gift certificates to local restaurants as an incentive for those who complete.

In summary, the project is complete with the caveat that we would have liked to have completed additional beta testing. Phase two (NSF ATE Project # 0302864) of this project will add an Intelligent Tutor System for user feedback and instructor-like help to the model and there may be time available to do additional beta testing in this phase of the project.

The simulations are the heart of the exercises and have multiple functions:

1. The simulations provide an environment in which the student users can test the functionality of their PLC programs in realistic process simulations and allow the user to make interactive measurements and to calibrate process instruments and to test them within the simulations.
2. The virtual exercises interact directly with the user and the simulated processes. The user actions directly influence the simulated process and the user can observe the result of correct or incorrect actions. Any error on the user's part will

cause problems to occur in the process. The user can observe the process in real time.
3. The simulations have routines running in the background that 'observe' student activity in much the same way a live instructor would, and like a live instructor, will upon request by the user provides troubleshooting feedback. The user can then correct the problem and retest their solution.
4. Incorporated into the simulation is a reporting mechanism that informs the instructor of student progress.

We believe this model has broad applicability for the experiential or laboratory exercises of other technical disciplines.

<u>Aspects where the project is either on schedule or ahead of schedule</u>
The project is complete although additional beta testing would have been desirable.

<u>Small additions to or small changes to project</u>
No significant changes have been made to the project goals.

<u>Difficulties in achieving milestones and potential solutions</u>
One significant difficulty occurred after completing the Year One modules. The instructions were written in the authoring tool Macromedia Authorware. We upgraded to the latest version in Year Two after completing the Year One modules. After we received feedback from beta testers, we opened the project to make changes. Opening the project with the new version caused unforeseen results because some button protocols were different in the new version and this resulted in scores of broken button links. We also discovered we could not go back to the earlier version and spent three weeks finding and fixing the broken links.

The primary difficulty has been getting beta testers to complete the beta tests. We believe we now have a strategy to provide the incentive to complete for future projects.

User feedback in a virtual environment has always been a challenge for any form of distance education with typical response time from an instructor varying from 24 to 72 hours when a student asks for help. While we have created a context sensitive feedback system that gives users assistance when they make mistakes, we believe increased sophistication of the help system would make the help system more useful. In Phase II (NSF ATE Project # 0302864) we plan to add an artificial intelligence tool to solve this difficulty.

Major changes in scope of project
No major changes.

Significant carry-over of funds (> 20%)
There are no carry-over funds.

c. Project Training and Development

At present, the only faculty involved in the project are the developers and collaborators. We have 15 instructors from other colleges who have expressed an interest in evaluating the product. We will be contacting them as soon as we complete local beta testing.

d. Outreach Activities

Dissemination activities such as presentations, outreach to schools, work with other institutions, work with industry
In 2002, we made four presentations at national conferences. We presented at the Eighth Annual ATESM (http://atesm2002.com) conference of the Maricopa Advanced Technology Education Center (MATEC) and the 2002 Critical Issues and Best Practices conference of the Center For The Advancement Of Process Technology (http://www.captech.org/cibpinfo2003.htm). We also had a tabletop presentation at the ATE PI conference.

Cisco Learning Systems has expressed significant interest in the model we have developed and also indicated an interest in participating in the Phase II Intelligent Tutor augmentation of the project (Project # 0203864). Stottler Henke Associates Inc. is also interested in the model and will be participating in the Phase II project. Stottler Henke has an Intelligent Tutor authoring system that we believe will significantly improve the embedded feedback of the simulations.

Dissemination activities such as publications, videos, software, Web site, and major articles or publications
The courseware is packaged as a hybrid Web/CD combination with control and reporting delivered via the Web and high bandwidth material and delivered on a CD ROM. We are in preliminary discussions with Prime Media as a potential marketing agent.

Impact information on students, faculty, and institutions, including numbers (i.e., Include information on how faculty, students, and institutions have changed and how many of each where impacted)

As a result of the presentations at national conferences, we have had a good deal of interest in the project. Thirteen colleges have expressed an interest in testing the finished product with the intent to use the material at their respective colleges. We have had preliminary discussions with a courseware vendor interested in distributing the final project.

It is too early to ascertain the impact or numbers. We anticipate a large audience for this project. Representatives from 13 colleges and industry groups have expressed interest in the project. These include Lively Technical Center, Texas A & M, Pensacola Junior College, Texas State Technical College, Albuquerque Technical Vocational Community College, Mesa Community College, University of Arkansas, Mott Community College, Austin Community College, Community College of Allegheny County, Chemeketa Community College, the Grand Isle Group, and the Semi group of semiconductor manufacturing vendors. If all participated, this would represent over 1000 students per semester.

<u>Awards, special contributions, major innovations, etc</u>
In discussions with industry representatives, it appears that using the simulations to both demonstrate and evaluate is an innovation. The simulations provide the similar types of interactivity as the site-based PLC class.

As a result of the current NSF project, Doyle Meyer was selected by MATEC as an 'Outstanding Faculty Member' and invited to present along with nine others selected from colleges across the nation having Manufacturing Technology programs at its Learning Inventions Lab conference. There was a very good response from attendees with numerous requests for the material as soon as it is available.

3. Publications and Products

    a. Other Specific Software

        i. <u>Description</u>
        Virtual Laboratory Software. At the end of year two of a two-year project, we have developed fifteen virtual laboratory exercises for an Introduction to Programmable Logic Control (PLC) class and eleven exercises for an Introduction to Process Measurement class. These exercises are designed to supplement and not replace the content portion of the curriculum. They are intended to be a substitute for a portion of the laboratory or hands-on exercises. These exercises are

delivered through a hybrid combination of Internet and CD ROM to a PC at any location that has an Internet connection.

If distance education for technical disciplines is to have a viable future, we need to design curricula that support the traditional laboratory experience in a virtual environment.

This project uses simulations to provide an environment in which the students can perform experiments and practice competencies learned in content modules. The simulations are non-sequential thus allowing the student some freedom to experiment beyond the confines of the defined exercises. The simulations also assess student learning and provide feedback to both student and instructor.

The class chosen for the first year of the project requires the student to write programs for a Programmable Logic Controller (PLC). Students then download the programs to a fully functional virtual PLC. The simulations are fully functional processes that are controlled by the PLC program. In the background, the simulation evaluates the effectiveness of the student's program and upon request from the user, will provide feedback on how to make corrections when the program does not function correctly. The simulation also stores data about student progress and makes that data available to the instructor.

The second year project creates similar simulations in which the student can observe the interchange of measurement variables within a functioning process. Our first objective is that the students understand the raw measurement of Pressure, Level, Flow and Temperature within the process. The second objective is that they demonstrate the ability to calibrate industry standard transmitters that convert the raw measurement data into the standard process signals used in process control.

ii. Sharing Software

As a result of the presentations at national conferences, we have had a good deal of interest in the project. Thirteen colleges have expressed an interest in testing the finished product with the intent to use the material at their respective colleges. We have had preliminary discussions with a courseware vendor interested in distributing the final project. We will also integrate the material into our programs as is appropriate.

4. Contributions

   a. <u>Within Discipline</u>
      We have developed virtual laboratory exercises for distance learning using simulations to provide an environment in which students can demonstrate competencies and which also assesses student performance and provides feedback to both student and instructor. The classes chosen are common to the Controls Technology and Manufacturing Technology curriculum.

      The experiential or laboratory exercises have long been recognized as a critical component of technical education. With the advent of distance learning, thousands of multimedia titles have been written, but little attention has been given to the hands-on component of the distance education curriculum. Without the experiential component designed and developed for the virtual environment of the Internet, distance education will be limited in its capabilities. These modules provide an opportunity for students to experience laboratory exercises in a virtual environment.

   b. <u>Outside of Discipline</u>
      We believe the techniques and processes developed for this project are applicable to other disciplines, but our focus is on manufacturing and automation.

   c. <u>Human Resource Development</u>
      This project has the potential to make distance delivery of technology training feasible. As such, it has the potential of making technology training more widely available, thus increasing the size and distribution of the high tech workforce.

   d. <u>Resources for Research and Education</u>
      A successful model for a virtual laboratory will expand the capability of colleges with limited resources to meet the educational requirements of a high tech workforce. With the technology currently available, we do not anticipate that at this time the need for site-based laboratories can be eliminated nor would it necessarily be desirable to do so. However, if 60-80% of the student's laboratory experience could take place in a virtual environment, the resource-limited college might be able to offer educational programs that would be impossible otherwise.

Attachment to Project Activities

INSTRUCTOR EVALUATION FORM

Please help us develop the best possible instruction by describing your perceptions of each module and answering each question in this evaluation. Your feedback will be used to revise and perfect the instructional materials. Also, please share your ideas on additional learning activities that you feel should be incorporated in each module. It is important to us to leverage your educational expertise to create the most robust, motivating, and effective learning experiences for students.

Directions for Completing this Form

Each evaluation item is presented as a question. W*hen you choose a "no" response:*
(a) Describe how you think the instruction can/should be improved and (b) Identify specific instructional elements (parts of the material you are reviewing) that are deficient. Indicate your level of agreement or disagreement by choosing one of the following responses:

1 – Definitely Yes 2 – Probably Yes 3 – Probably No 4 – Definitely No

Is the text material presented in an interesting way that motivates learning?

Rating	Explanation

Is content organized in a way that helps learners understand and remember key concepts and facts?

Rating	Explanation

Does the graphic material (pictures, animations, and simulations) provide an interesting presentation that motivates learning?

Rating	Explanation

Do the exercises provide effective practice that will help students acquire relevant and appropriate knowledge?

Rating	Explanation

Do activities and exercises provide experience that help students develop useful skills?

Rating	Explanation

Will the performance assessment (final test) effectively measure students' achievement of the learning objectives?

Rating	Explanation

Are items in the performance assessment (final test) set at the right level of difficulty?

Rating	Explanation

Do the words (e.g., labels or descriptions) that appear with graphics clearly convey information and identify important parts of pictures and diagrams?

Rating	Explanation

Is there enough detail in the graphics to enable students to grasp the concepts?

Rating	Explanation

Are there enough graphics or other visual elements to facilitate learning?

Rating	Explanation

Is the text content (e.g., phrases, sentences, terms) presented in a logical order?

Rating	Explanation

Do learning objectives address the appropriate knowledge and skills for the topics being covered?

Rating	Explanation

Is the list of objectives sufficient (enough objectives) for the topics being covered?

Rating	Explanation

Do the stated learning objectives correspond to the content being material presented?

Rating	Explanation

Do the instructional activities provide students with experience and practice that directly address the learning objectives?

Rating	Explanation

Are the directions and/or resources provided in the module sufficient to complete each learning activity?

Rating	Explanation

Is a scoring method provided (e.g., assignment of points to correct answers) that will produce a fair, unbiased, and accurate judgment of learners' mastery?

Rating	Explanation

Approximately how many individuals in your organization could benefit from this educational material?

Rating	Explanation

Approximately how many hours did it take to evaluate this educational material?

Rating	Explanation

Functionality Evaluation Form

Please help us develop the best possible functionality by describing any problems that you discovered while using the CD-Rom. Place an X in the section of the module, type the number of the page, and then describe the problem that you encountered. This helps us to fix as many errors as possible before we release the CD-Rom. Thank you for Beta Testing this project!

Overview					**Describe Problem**
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Overview					**Describe Problem**
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Overview					**Describe Problem**
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Overview					**Describe Problem**
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Inputs & Outputs				**Describe Problem**
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Page:				

Inputs & Outputs				**Describe Problem**
I	E1	E2	E3	
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Inputs & Outputs	Describe Problem
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Combination Logic	Describe Problem

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Combination Logic	Describe Problem

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Counters	Describe Problem

I	E1	E2	E3

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Counters	Describe Problem

I	E1	E2	E3

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Counters	Describe Problem

I	E1	E2	E3

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Counters	Describe Problem

I	E1	E2	E3

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Counters	Describe Problem

I	E1	E2	E3

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Counters	Describe Problem

I	E1	E2	E3

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Timers	Describe Problem

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Timers	Describe Problem

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Sequencers	Describe Problem

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