# Assessment of Remote Experiments and Local Simulations: Student Experiences, Satisfaction and Suggestions

Jim Henry
Department of Chemical and Environmental Engineering
University of Tennessee at Chattanooga
Chattanooga, TN 37403-2598

Richard Zollars
Department of Chemical Engineering
Washington State University
Pullman, WA 99164-2710

Abstract

This paper has a comparison of student reactions to having laboratory experiments conducted with simulation software and being conducted remotely through the Web. The students in a process controls course were exposed to both simulation and remote experiments at different times during the course. We surveyed the students at the end of the course about aspects of the two methods of conducting experiments. These surveys are one of the "outcomes" of the course and are tabulated here. This paper discusses some changes that can be instituted to capture the best learning features of the two methods of having students learn from the laboratory.

Introduction

Providing hands-on, or learn-by-doing, experiences for engineering students is often complicated by either a lack of equipment, technician support or both. Yet most topics in chemical engineering are best learned via a learn-by-doing approach. Computer simulations have been used in lieu of a truly hands-on experience but these are often lacking in the fullness of details that real systems provide. With the advent of high-speed Internet communications an alternative approach to providing hands-on experiences has become possible – remote operation of real equipment. Such remote operation experiences are fully learn-by-doing with nearly all the positive and negative aspects of true hands-on laboratory work.

This past year the process control class at Washington State University was taught using both of these approaches. Computer simulations for process identification and control were provided using Control Station® (http://ww.controlstation.com). Remote operation of actual equipment for the same purposes was provided via an Internet connection to the Resource Center for Engineering Laboratories on the Web (http://chem.engr.utc.edu) at the University of Tennessee at Chattanooga (UTC). The control class at Washington State University was divided into two groups – one to use Control Station® and the other to access the site at UTC. On subsequent assignments the groups were switched so that each group had an equal opportunity to conduct experiments via both computer simulations and remote operation. At the conclusion of the course the students were surveyed about their experiences with each type of “hands-on” experience.

Procedure

The class had 19 students in it – all in the first semester of their senior year. The class is typical of many ChE-based control class with Course Objectives for the students of being able to:

1) analyze the dynamics of process operations
2) understand the dynamic response of various operations
3) understand PID controllers for process operations based on both theoretical and empirical process characterization

The outcomes arising from the objectives outlined above are intended to partially satisfy ABET outcomes a, c, e, and k as well as the AIChE outcomes of demonstrating a working knowledge of material and energy balances applied to chemical processes, process dynamics and control, and appropriate modern experimental and computational techniques.

To achieve these objectives most of the homework assignments in the first half of the course were textbook problems. Virtually all of the homework assignments in the second half of the course, however, required the students to collect “real” data about a process. This could be accomplished by either dynamic simulation of process operations or by running experiments on real equipment and observing the dynamics.

We did a total of 8 laboratory assignments where students had to take data from either the experiment on the web site or from Control Station. The first six of these assignments were run using the level control experiment and the last two were run using the temperature (heat exchanger) module. In both cases we split the class in half and had half of the class get data from Control Station and the other half from the web site. For each assignment the students worked individually to collect the data and perform the requested analysis.

The Control Station modules and the web-equipment control interfaces were analogous, so the assignments for each grouping of students were virtually identical. We alternated the site that each student used so that every student did three level experiments and one heat exchange experiment at the web site and the same number using Control Station. Table 1 shows the topics covered in each assignment as well as the student groupings assigned to each.

Table 1. Sequencing of lab assignments

| Assignment Number | Description | Control Station | Web exp'ts |
|---|---|---|---|
| 1 | Liquid Level – Process Dynamics | Group A | Group B |
| 2 | Liquid Level – Effect of gain on P controller | Group B | Group A |
| 3 | Liquid Level – Effect of gain and integral time on PI controller | Group B | Group A |
| 4 | Liquid Level – Closed loop tuning | Group A | Group B |
| 5 | Liquid Level – Open loop tuning | Group A | Group B |
| 6 | Liquid Level – Integrated error tuning | Group B | Group A |
| 7 | Temperature – Use of "rltool" function (Matlab) for tuning | Group A | Group B |
| 8 | Temperature – Use of "bode" function (Matlab) for tuning | Group B | Group A |

Examples of typical assignments for the liquid level and temperature modules are the first two attachments. Examples of the typical screens the students see when conducting the liquid level experiment on Control Station and at the UTC site are shown following the assignment examples.

Survey of Students at End of Course

We were interested in the student response of the two methods of conducting laboratory experiments. We had the students answer survey items listed in Table 2. The responses were coded with "Strongly Disagree"=1 and "Strongly Agree"=5.

Table 2. Survey Results

| Item | Survey Statement | Response Avg ± SD |
|---|---|---|
| 1 | The instructions provided within the simulation were more understandable than those at the web-experiment site | 3.2 ± 0.8 |
| 2 | The web-experiment site was more readily available than was the simulation | 1.4 ± 0.8 |
| 3 | The simulation was easier to use than was the web-experiment site | 4.0 ± 1.0 |
| 4 | The web-experiment site provided a more real life experience than did the simulation | 3.4 ± 1.1 |
| 5 | The visual aspects of the gravity drained tanks experiment at the web-experiment site were better than the visuals in the simulation | 2.8 ± 1.0 |
| 6 | I feel that I learned the material better using the simulation rather than the web-experiment site | 3.2 ± 1.1 |
| 7 | I would prefer using the web-experiment site rather than the simulation on assignments in the future | 2.0 ± 1.0 |

Over the time of the laboratory assignments, the students ran a total of about 700 experiments using web-connected equipment and untold number of simulation experiments. The sense of the response here indicates a student preference towards using the simulation rather than the web experiments (Items 2, 3, 5 and 7). The student response showed no significant difference between the two methods on understandability, real life nature of the experience and learning.

The above observations are those of experienced observers (the two authors) and are anecdotal and not now statistically based.

We also asked them five open-ended questions to give us feedback on their experiences. The questions were

1) The best feature(s) of the simulation are …
   Near unanimous agreement was expressed that the best feature of the simulation was that it was fast (simulation time could be faster than real time) and always available without a queue.
2) The best feature(s) of the web-experiment site are …
   Near unanimous agreement was expressed that the best feature of the web experiments was that it was a real experiment, including the visual observation, even with its real-life quirks.
3) The feature(s) of the simulation that I would like to see improved are …
   Some students wanted more access to the simulation program (home copies, for example) and more built-in instructions.
4) The feature(s) of the web-experiment site that I would like to see improved are …
   Most students wanted the real equipment experiments to run faster. Some students suggested a scheduling or queuing system that allowed access in a fairer (?) way than first-come, first-serve. Some students wanted better and more instructions and diagrams.
5) Other comments.
   Many students recognized the value in the "real life" experiments and still preferred the simulation. Several suggested a smaller fraction of experiments on the web-experiment site to alleviate the bottleneck created by many students needing a number of real experiments completed.

The complete set of student responses are all available on the web at http://chem.engr.utc.edu/ASEE/2003/National

Discussion

As we read through the comments the ones that stand out are the comments about how hard it was to get to the web-experiment site because of others in the class. Consider that there were, at most, only 10 students trying to get to the web-experiment site from WSU, and that they all had the assignments at least a week in advance of when they were due. It seems that the problem was that they were trying to treat this like a normal assignment, i.e., waiting until the last moment to get it done. Then when all 10 (or maybe only 7 or 8) tried to get to the web-experiment site the evening before the assignment was due (it was an 8:00 am class) they ran into difficulties.

We would estimate that if students were given both simulation and hands-on-hardware experiments in a finite laboratory, the student responses would be similar to those we found here. We did not attempt any quantitative assessment of differential learning outcomes based on the method of experimentation. Based on anecdotal observation, there was no indication that either method of experimentation had a significantly greater value for the students in learning the concepts of system dynamics and control.

We plan on continuing this study and will work to make the conclusions quantitative.

In terms of deciding which method to use for a class, here are the considerations that we would highlight. If the instructor has Control Station licenses and is familiar with Control Station use, it is a powerful stand-alone tool for helping to teach the analysis and design of control systems. Otherwise, the web-connected experiments provide a tool that can be equally powerful. A pro for Control Station is that multiple students can do simulations simultaneously. A pro for the web-connected experiments is that multiple students can *view* the experimental results simultaneously. A con for the web-connected experiments is that only one physical experiment can be running at any one time and the running of the experiments require an active on-line connection to the experimental equipment.

**ChE 441** **Washington State University**
**Process Control** **Department of Chemical Engineering**
**Fall, 2002** **Richard L. Zollars**

Homework Assignment #15
Due: October 23, 2002

We again are going to use Control Station and the site at the University of Tennessee – Chattanooga to examine various tuning strategies. Whichever system (Control Station or the UTC system) you used on the last assignment (Assignment #14) you should use the other system for this assignment.

Use either the Gravity Drained Tanks (Control Station) or the Level (UTC) system (use the Large Tank) to answer the following questions.

a) Either leave the controller in "Manual Mode" (Control Station) or use the "Step" input function from the UTC site. Follow the procedure on p. 310 of the text to conduct an open loop test. This means changing the "Input" value for the UTC site or changing the "Controller Output" in Control Station. Record the process response curve. Manually (i.e., don't use the "Design Tools" available in Control Station) determine the values for the gain, time constant and dead time for a first-order plus dead time model for this process. You may use any of the techniques described on pages 312-314.

b) Using the values from part a) and the formulae given in Table 7-2.1 set the parameters for a PI controller. Now go back to UTC or Control Station and turn on a PI controller with the parameters you determined above. After reaching a steady-state input a step change in the set point and check the output. Did a quarter decay ratio result? What is the decay ratio?

c) Adjust the gain until a decay ratio of 0.25 is obtained for a set point change. What is the value of the gain? Why is it different from the value given by Table 7-2.1?

Assignment #17 Due: November 6, 2002

We are again going to use both Control Station and the UTC site. If you used Control Station for Assignment #16 use the UTC site this time. If you used the UTC site for assignment #16 use Control Station this time. We are going to use a new module in each this time, however. In Control Station go to the case study marked "Heat Exchanger". ON the UTC site go to the Process Control site and select the "Temperature" module. (NOTE: On the UTC site you will no longer be able to see what is happening.) Conduct an open-loop test to determine the process parameters for a first-order plus deadtime model. When doing this at the UTC site make sure that the Hot Water Outlet is the control variable.

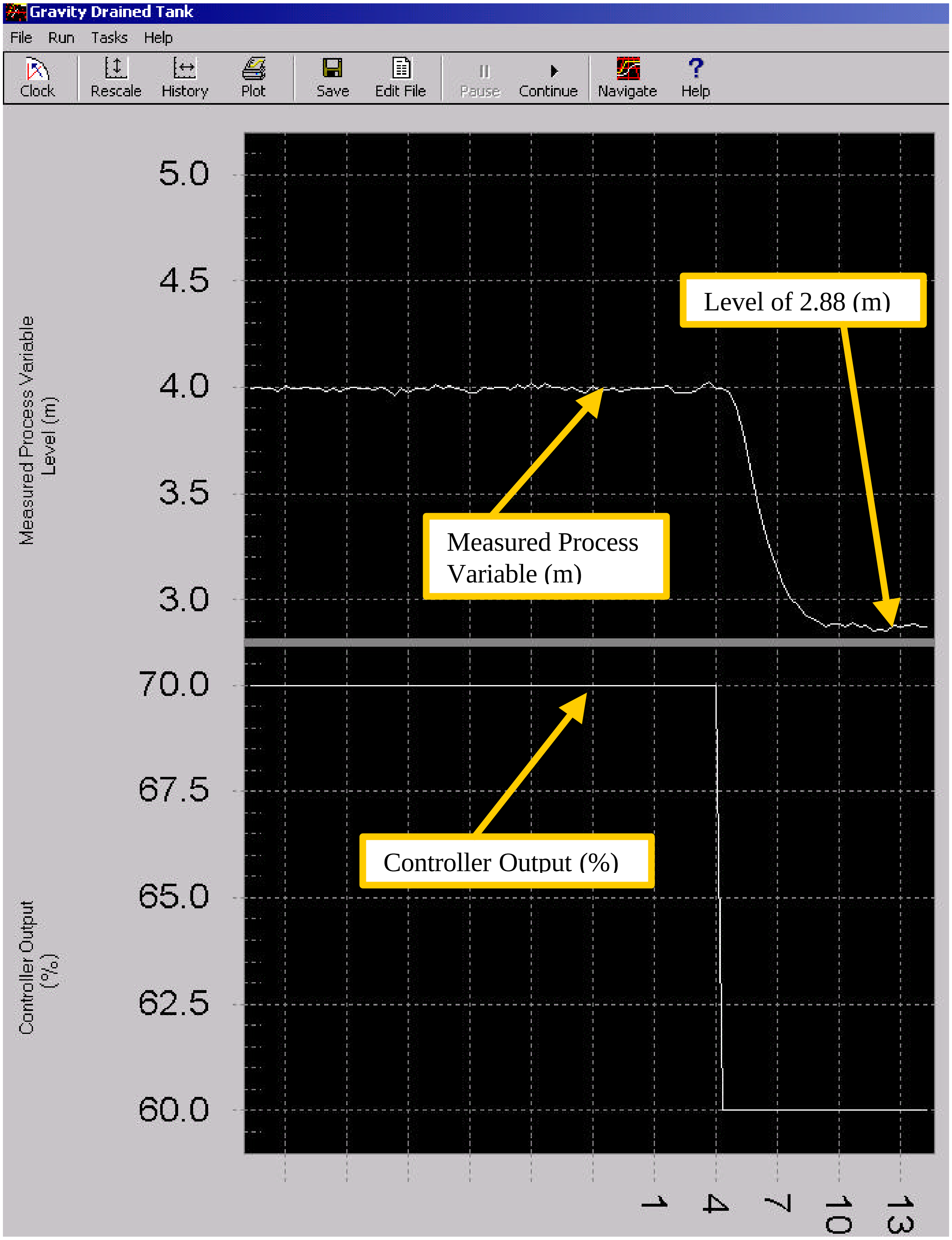
Use these parameters and Table 7-2.1 to determine the tuning parameters for a PI controller. Enter the transfer functions for the controller and process into Matlab. If your open loop test gives you a negative number for the process gain you will have to incorporate the negative sign into the numerator or denominator of the transfer function, as Matlab does not allow negative gains. Then, using the rltool program in Matlab determine:

1) the ultimate gain for the controller
2) the controller gain needed to obtain a quarter-decay ratio response to a unit step change input

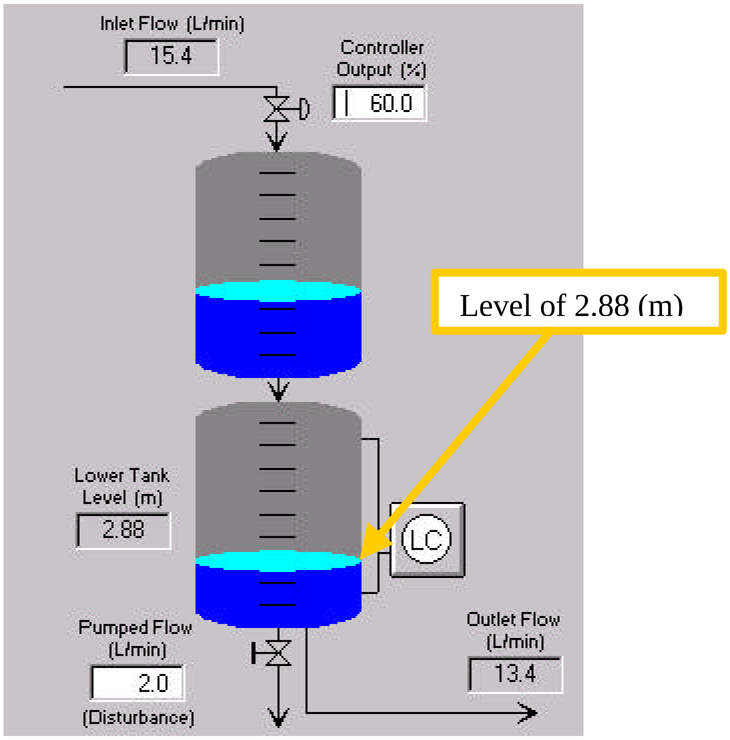
Go back to either Control Station or the UTC site, enter the parameters for a PI controller that you obtained from Matlab and perform a step test (Note: When doing this at the UTC site make sure that the initial hot water temperature is 30°C or higher. Now go back to Matlab and find the tuning parameters for a quarter decay ratio response if you used an integral time that was twice the value you obtained from Table 7.2-1. Run an experiment using either Control Station or the UTC site using the parameters predicted by Matlab for this situation. Finally go back to Matlab a third time and find the parameters for a quarter decay ratio response using an integral time that is one-half the value predicted by Table 7.2-1. Return to either Control Station or UTC and run a step change experiment using this third set of parameters.

What effect did changing the value of the integral time have on the form of the response curve? Did you obtain a quarter decay ratio response for each value of the integral time? If not, why not?

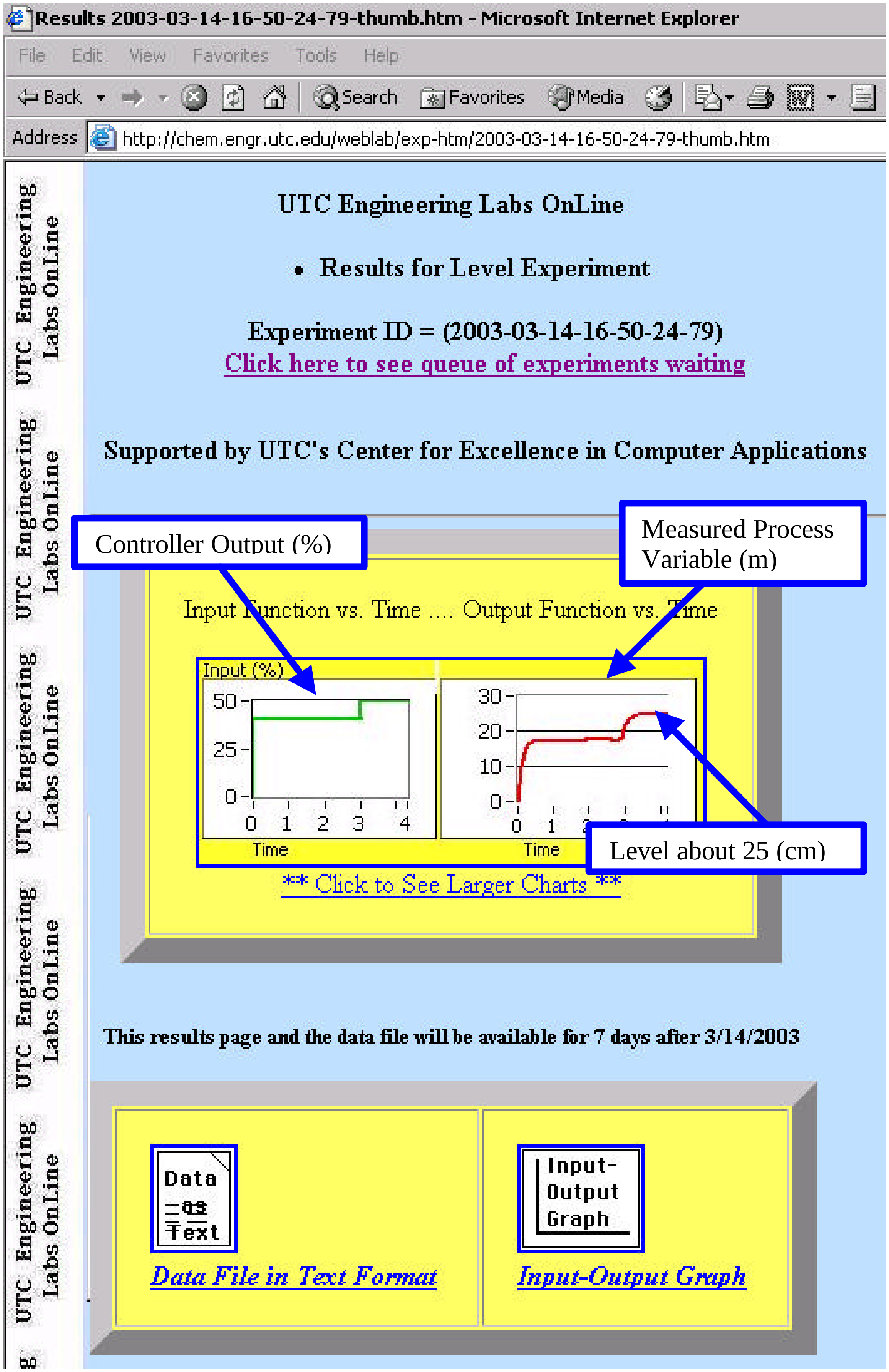
When submitting your assignment make sure to turn in the output from your open loop test, the Matlab root locus plot used to determine the ultimate gain and the quarter decay ratio response, and the response curves from each of the subsequent experiments.



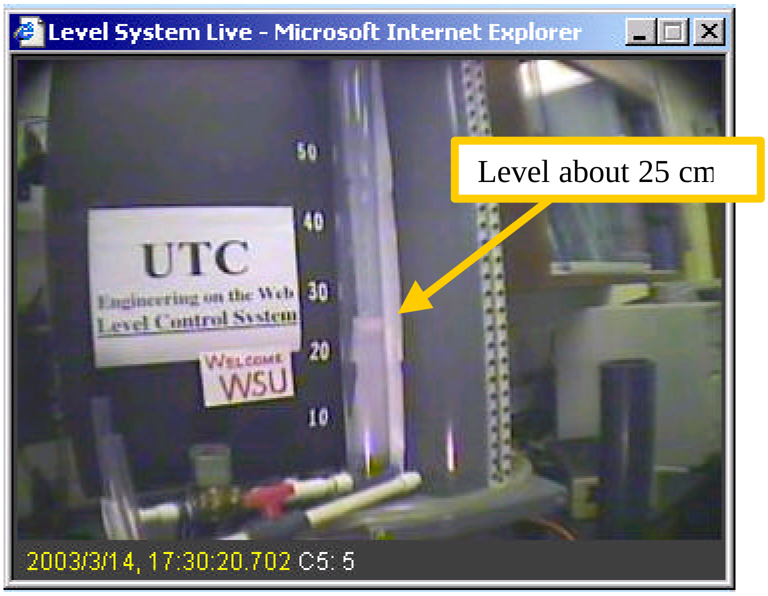

Sample screen that students view from Control Station. This shows the process variables as functions of time. This is for a step response test.




Sample screen that students view from Control Station.
This shows an animated diagram of the level in the lower tank.




Sample screen that students view from the Web experiment. This shows the process variables as functions of time. This is a step response test.




Sample screen that students view from the Web experiment.
This shows live video of the level in the tank.

JIM HENRY

Dr. Henry is a professor in the area of chemical and environmental engineering at the University of Tennessee at Chattanooga. He received his Ph.D. from Princeton University. He has been teaching engineering for 35 years. He is interested in laboratory development for improved learning.

DICK ZOLLARS

Dr. Zollars is a professor in, and chair of, the Department of Chemical Engineering at Washington State University. He received his Ph.D. from the University of Colorado. He has been teaching engineering for 25 years. His interests are colloidal/interfacial phenomena and reactor design.