COMPUTER-MEDIATED, COLLABORATIVE LEARNING IN CHE

At the University of Ottawa

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The undergraduate chemical engineering curriculum at the University of Ottawa includes an introductory course in process dynamics and control. Taught to third-year students during their winter semester, it consists of three hours of lectures per week. A typical class has twenty-five students.

As part of a University initiative to incorporate computer technology in the classroom, I received a grant to develop a computer-based version of this course. Using this funding, an undergraduate student from our co-op program, Alain Turenne, and I constructed a series of computer-based modules and interactive simulators to allow independent study of the course material.

With the core material now available in a self-paced, computer-mediated format, I was able to rethink how I managed the lecture hours. I had from time to time incorporated collaborative, in-class problem solving sessions in my lectures, whereby students worked together in small groups to solve problems related to that day's topic. I decided to make this student-driven activity the focus of all of the lecture periods. This paper describes how I combined computer-assisted learning with collaborative learning in this course and presents both students' and instructor's impressions regarding the effectiveness of the approach.

COMPUTER-MEDIATED LEARNING COMPONENT

The computer-mediated portion of the course consisted of a series of nine modules. The material for the modules (Table 1) was drawn largely from Thomas Marlin's text,[1] with additional material taken from other standard textbooks in the field.[2-4] Each module provided a condensed review of its topic, although it included more detail than one might expect from lecture notes alone.

The modules employed interactive text, graphics, and animation to present the core material of the course. We built these using Asymetrix, Inc.,'s authoring software, Multimedia Toolbook. Toolbook provides a powerful, object-based graphical framework for producing computer-based training software for Microsoft operating systems (Windows 3.x, Windows 95, and Windows NT 4). Beginning with an empty window, we added various components (such as buttons, text fields, images, animation, etc.) to create a page within the module. These components were then scripted to respond to keyboard and mouse events (such as button clicks), imparting to the page its interactive qualities (see Figure 1). Finally, the nine course modules were linked through a graphical menu (see Figure 2).

To supplement the Toolbook modules, we constructed four dynamic simulators that students later used to explore the effects of process-model parameters and controller-tuning parameters on system dynamics. We built these using Delphi, an object-oriented, visual programming language based on Pascal and produced by Inprise (formerly Borland) Corporation. The Delphi development environment is similar to that of Toolbook; programmers add visual components to empty windows and then write the requisite code for these components as well as for the numerical routines. The final simulators included a graphical user interface through which students could adjust model parameters and view plots of the process response (see Figure 3). Further, students could run these simulators directly from the modules.

We designed and constructed the modules and simulators over a one-year period prior to introducing them into the course, after which time we installed them on a PC network

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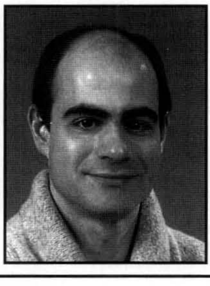

TABLE 1
Module Content

Module	Contents
1. Introduction to Process Control	• definitions • principal control components • feedback vs. feedforward control • calculating control benefits
2. Mechanistic Modeling	• modeling methodologies • defining a modeling approach • developing the model
3. Empirical Modeling	• motivation for empirical modeling • procedural approach to empirical modeling • statistical model building
4. Analyzing Process Dynamics	• dynamics of linear lst- and 2nd-order systems • SISO and MIMO systems • Laplace domain for linear systems • transfer functions and block diagrams • frequency domain for linear systems
5. The Feedback Control Loop	• the feedback loop • process elements and instrumentation • block diagrams revisited • control performance measures
6. PID Controllers	• the feedback loop revisited • proportional mode • integral mode • derivative mode • PID control
7. Stability Analysis	• stability and process control • stability criterion • Routh analysis • direct substitution method • frequency response analysis
8. Tuning PID Controllers	• considerations and criteria for tuning • Ciancone correlations • Ziegler-Nichols correlations • issues of fine tuning
9. Digital Control and Filtering	• digital feedback control algorithms • signal filtering • valve control and failure modes

located in the engineering building at the University of Ottawa. The classroom housing these PCs was designated a "quiet room" so that the students could study the modules at their convenience. In addition, I constructed a course web site from which the students could download the modules to run from home. The site also contained supplementary course material and a Java applet for retrieving marks on-line.

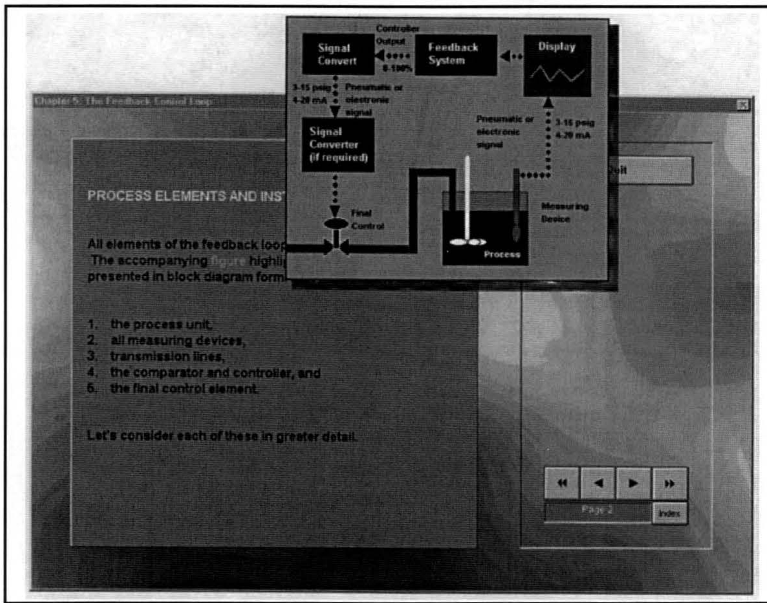

Figure 1. A screen capture of a page from one of the course modules. The pop-up box is animated.

COLLABORATIVE LEARNING COMPONENT

A typical single semester course in chemical engineering at the University of Ottawa consists of three lecture hours per week; these are normally delivered in two ninety-minute sessions. In the process control course, however, I combined the two weekly lectures into a single, three-hour session. While one would expect a lecture of this length to tax even those with ironclad concentration, it proved well suited to the collaborative, problem-based sessions used in this course.

Each week the students were given an assignment that was due two days before the next lecture. In addition, they were assigned a module (or portion thereof) to review for the following week. Each student was asked to submit, together with his/her assignment, a review sheet that highlighted any confusion with the subject matter contained in that week's module. The review sheet also contained space for the student to provide feedback re-

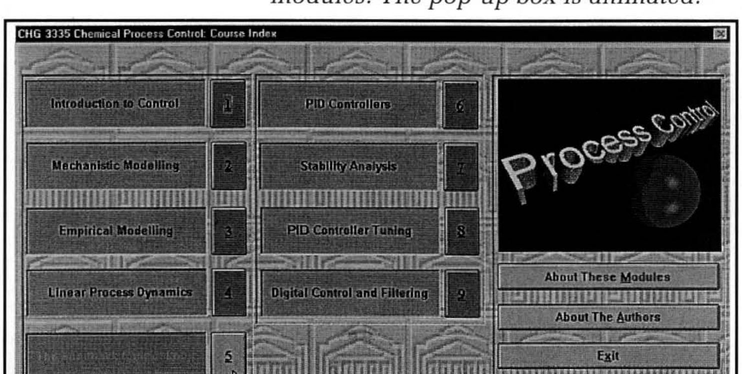

Figure 2. A screen capture of the modules' menu window.

garding the design of the module.

Prior to each weekly session, I would look over the review sheets, noting the areas of concern raised by the students. I would then design a set of short questions (normally requiring no more than fifteen minutes to complete) and a brief fifteen-minute lecture that focused on the current module's content and addressed those problem areas identified by the students.

The three-hour session would start with the prepared lecture, after which time students would move into small groups. (These groups were formed at the beginning of the term.) Each group would be assigned the same in-class problem and given a short period of time to work on it. During this time I would move through the class and provide limited guidance where needed. I would then randomly select one group from the class to present its solution to the problem. While no mark was given for "right" answers, the group was evaluated on its understanding of the problem and its ability to formulate a solution method. In this way the group presentation served as a springboard for class discussion regarding the problem and its solution. A typical three-hour lecture would include several of these exercises.

ASSESSMENT

The Students' Perspective

Since the standard course evaluations issued by the University of Ottawa do not directly address matters concerning course delivery modes, I undertook my own student evaluation approximately half-way through the term. Assessing the students' reaction to the new teaching style at this stage in the course also permitted me time to make any changes that seemed necessary from the students' perspective.

In addition to the standard questions appearing on the University of Ottawa's form, the evaluation included three questions relating to the new teaching style. The first of these read

> *Compared to other lecture styles that I have experienced I find the approach in this class to be..."*

and offered five choices from excellent to very poor for the student designation. The second question was

> *I find the time spent on in-class problem solving to be...*

with choices of "Very Helpful" to "A Total Waste" on a scale of five. The final question

> *I find the computer-based modules as learning aids . . .*

offered the same five choices listed under the first question.

The thirty anonymous responses to these three questions are presented in Figures 4a, b, and c, respectively. Overall, the students preferred this form of lecture to the standard, passive approach. As the responses to question 2 demonstrate, students particularly enjoyed the opportunity to apply their problem-solving skills in a structured, professor-mediated format. At least one student also saw value in having to present a solution to the rest of the class, as (s)he noted in the following comment:

> *Although I do not particularly like speaking in front of the class, I find presenting assignments and in-class problems useful. It forces me to keep up with the course material so that I know what I'm talking about when presenting.*

Of course, not all students saw it the same way. Another said

> *I think in-class teaching should be more emphasized since it benefits the whole class, rather than in-class problems which*

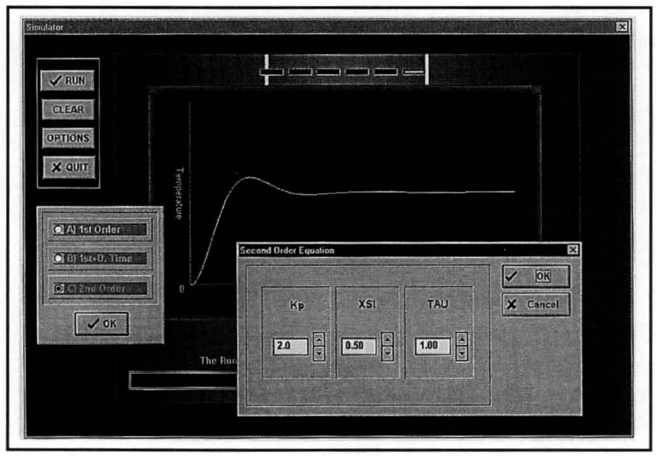

Figure 3. *A screen capture of one of the dynamics simulators accompanying the course modules.*

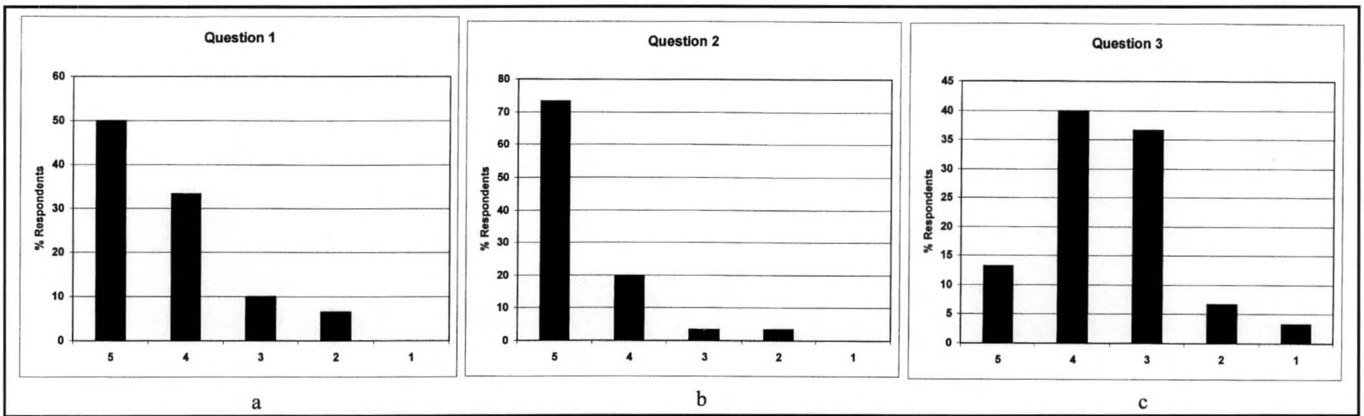

Figure 4. *Student responses to questions 1, 2, and 3 of the midterm evaluation.*

usually benefit the group doing the problem.

(I found this remark puzzling, since all groups were required to complete each question and since no group knew ahead of time who would be presenting the solution to the class.)

The overall response to question 3, though favorable, suggests that students were somewhat less enthusiastic about having to review the modules each week. The weekly feedback regarding the modules' structure and content was generally positive, leaving me to suspect that some students simply objected to having to spend time reviewing them outside of class. (It is worth noting that the average module would require less than three hours to complete, implying under 2.5 review hours per week for the course.) Further, since they could not print out the modules' content directly, students had to generate their own course notes. Not surprising, several students stated on the evaluation sheet that they would have preferred the option to print out the module content. But this limitation was deliberate, since I felt that the note-taking was valuable from a pedagogical perspective.

The Professor's Perspective

Admittedly, the combined collaborative, computer-mediated learning methodology used here required more work outside of the classroom: customizing each weekly session to address student comments, maintaining the course web site, and updating the course modules. But I did not find that any of these tasks required an inordinate amount of time.

The most significant changes for me as instructor lay in the classroom. First, the class became student-centered rather than professor-centered. This altered my role significantly from one of lecturer to one of facilitator—it also raised the students' level of interest during the lecture. The students seemed to quickly adapt to their new, and more prominent, role; in fact, the overall mood in the classroom was very positive. (It is worth noting that none of the students complained about the length of the weekly sessions, even though these sessions were twice as long as the standard lecture.) Attendance was also exceptionally good. Whether this was due to increased interest among the students in the course, or due to the fact that students were graded on their participation in the problem sessions, or attributable in varying degrees to both, is unknown. But the atmosphere within the class was significantly better, compared to other courses that I have taught using a more formal lecturing approach. Students in this class were far more inquisitive, eager to ask questions relating not only to the in-class problems, but to broader issues of process control. They were also far less hesitant to seek clarification during the lecture.

Clearly, this form of collaborative learning does not need to be supplemented with computer-based learning. The value of the modules, to my thinking, lay with their ability to present the conventional course material more effectively than paper handouts. In particular:

1. Being interactive, the modules engaged the students in the learning process (this is particularly true of the simulators, which allowed the students considerable freedom to explore the causal relationships in feedback control loops).
2. They allowed students to process information in a nonlinear, and consequently more flexible, fashion. For example, hyperlinks in the modules give students the choice of either delving further into a topic or continuing to the next one, without compromising the flow of the overall presentation.
3. They integrated several media forms (text, graphics, and animation) to present the subject matter, thereby offering various perspectives on the same topic.

The modules therefore provided added incentive for students to review the material ahead of time, which in turn contributed to the success of the classroom sessions.

CONCLUDING REMARKS

Collaborative learning is well established as an effective method for teaching engineering students. For example, Felder included in-class, small-group problem solving as part of a longitudinal study of student learning styles.[5] In that paper, he notes that students' evaluations were "consistently and overwhelmingly positive" and that their performance was significantly better. Of course, Felder's study incorporated cooperative learning, which goes well beyond the small group sessions employed here. But improved student attitudes that he observed are consistent with this study as well.

Finally, the teaching technique applied here requires that students undertake more independent study than might be expected with conventional lecturing. Computer-mediated delivery of the course material provides an attractive alternative to notes in this case, offering new approaches for students to assimilate both theoretical concepts and their ramifications in practical engineering problems.

ACKNOWLEDGMENTS

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