GRADUATE BRIDGING AND CONTINUING EDUCATION USING THE INTERNET

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The rapid growth of industries based on technologies that cut across multiple disciplines (*e.g.*, biotechnology) has increased the demand for students who are cross-trained in complementary disciplines. For example, students trained in both bioscience and chemical engineering are particularly well-suited for employment in the pharmaceutical industry. Cross-training options vary from taking a few selected courses in a second discipline to obtaining a full graduate degree in a second department. To meet the growing need for cross-trained employees, Michigan State University (MSU) has developed two three-credit semester courses, Foundations in Chemical Engineering I and II, for Internet delivery.

The original intent of the courses was to prepare students from chemistry, biology, and other physical sciences for graduate work in chemical engineering. We have found, however, that these courses also provide an excellent continuing-education option for engineers and scientists who want an overview of the core chemical engineering concepts. Consequently, the courses have been packaged into two programs that

- *Meet the needs of students bridging into a chemical engineering graduate program*
- *Provide continuing-education certification for professionals*

Bridging Program for Graduate Training in Chemical Engineering

The two courses can serve as the core of a bridging program that prepares students with BS degrees in a technical field other than chemical engineering for graduate training in chemical engineering. In general, such bridging programs provide sufficient background so that students can enter and successfully complete MS or PhD degrees in chemical engineering. The National Technological University (NTU) accepts non-chemical-engineering students who have performed well in these courses into its MS program in chemical engineering. As described in more detail later in this paper, however, bridging programs from one department to another vary, depending on the background of the student and the policies of the department.

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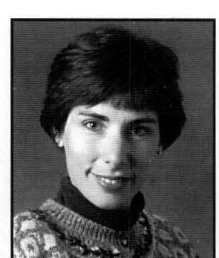

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Certificate Program for Continuing Education

The courses provide a continuing-education opportunity for science and engineering professionals who would benefit from knowledge of chemical engineering concepts, terminology, and calculation methods. The two courses include most of the foundational principles covered in the undergraduate chemical engineering curriculum. Environmental engineers, chemists, biochemists, mechanical engineers, agricultural engineers, food scientists, and others have taken these courses to enhance their technical backgrounds. A Certificate of Completion in Foundations of Chemical Engineering is awarded to students who perform at the grade level of 3.0/4.0 or better.

HISTORICAL PERSPECTIVE

The Foundations in Chemical Engineering course sequence is an Internet version of a two-course program that has been taught at MSU for more than 20 years. This bridging program has been effective in attracting high-caliber scientists into MSU's graduate program because it provides intensive and time-effective training. Twenty-four non-chemical engineering students entered our MS program via this program over a recent nine-year period. Of these students, 16 became MS students (some of our current MS students may continue for a PhD), three became PhD students, and five discontinued after completing the bridge course.

At MSU, students bridging into our graduate program are also required to take the first semester of the senior capstone design course and the process controls course. As a basis of comparison, those bridging students who completed Process Design and Optimization I received an average grade of 3.56/4.0. Those who continued in the graduate program earned an average graduate GPA of 3.68/4.0. These data indicate that the bridging program provides the chemical engineering fundamentals necessary for success at the graduate level.

In 1996, NTU began broadcasting the bridging program live via satellite, extending the course to a nationwide audience. Access to the courses was still limited by the number of satellite downlinks and conflicts with the schedules of prospective students. To further expand access, MSU completely redesigned the courses for Internet delivery. The new Web offerings, Foundations in Chemical Engineering I and II, were taught for the first time via the Internet during fall of 2000 and spring of 2001, respectively. NTU has adopted these new Internet courses for its bridging students.

COURSE STRUCTURE

Because of time limitations, only those topics considered central to chemical engineering are included in the courses. The objectives for selection of material are that the concepts be based on

- *Fundamental balances (material balance, energy balance, mechanical energy balance, momentum balance, phase equilibrium, reaction equilibrium)*
- *Fundamental transfer equations (Newton's law of viscosity, Fick's law, Fourier's law)*
- *Basic dimensionless correlations (friction factor, heat and mass transfer coefficients)*

The courses are homework-intensive and focus on developing problem-solving skills using chemical engineering principles. We intentionally limit the number of special topics and novel applications covered. These more specialized areas can be acquired by the students through independent study.

Foundations in Chemical Engineering I (three semester credits) includes content on material and energy balances, thermodynamics, and reaction engineering. The course topics include

- *Units and dimensional consistency*
- *Material balance procedures for single and multiple units including chemical reactions*
- *Energy balance*
- *Entropy balance*
- *Process thermodynamics*
- *Real gas properties*
- *Calculation of real gas enthalpies and entropies*
- *Raoult's law and modified Raoult's law*
- *Fitting kinetic rate constants*
- *Reactor design equations for batch, plug flow, and mixed flow reactors*
- *Series and parallel arrangements of reactors*
- *Reactor design for parallel reaction pathways and series reactions*
- *Reaction equilibrium*
- *Nonisothermal reacting systems*

A course overview with a complete lesson list is available at <http://vu.msu.edu/preview/che804/>. The texts used for this course are: *Elementary Principles of Chemical Processes*, R. M. Felder, R. W. Rousseau, 3rd ed., Wiley (2000); *Introductory Chemical Engineering Thermodynamics*, J. R. Elliott, C. T. Lira, Prentice-Hall (1999); and *Chemical Reaction Engineering*, O. Levenspiel, 3rd edition, Wiley, (1999).

Foundations in Chemical Engineering II (three semester credits) includes content on fluid flow and heat transfer, and mass transfer and separations. Course topics include

- *Dimensional analysis*

- *Introduction to fluid properties*
- *Macroscopic mass, mechanical-energy and momentum balances*
- *Calculation of drag forces and friction losses*
- *Pumping*
- *Design of flow systems*
- *Derivation of shell balances*
- *Microscopic mass and momentum (Navier-Stokes) balances*
- *Steady-state and unsteady-state heat conduction*
- *Analogies between momentum, heat and mass transfer*
- *Convective heat transfer*
- *Design of heat-transfer equipment*
- *Heat transfer by radiation*
- *Mass transfer by diffusion and convection*
- *Mass balances for differential and stagewise separations processes*
- *Design of gas absorption and stripping columns*
- *McCabe-Thiele distillation method*
- *Multi-component distillation*
- *Liquid-liquid extraction*

A course overview with a lesson list is available at <http://vu.msu.edu/preview/che805/>. The text used for the course is *Unit Operations of Chemical Engineering* (6th edition) by McCabe, Smith and Harriott, McGraw-Hill, New York (2001). Although this text covers many of the basics, a significant amount of supplemental material is provided in the lesson notes, especially in the area of microscopic (shell) balances.

The sequence in which some of the topics are covered is unconventional. For example, in a traditional chemical engineering curriculum, reaction engineering is typically covered after separations. We have combined reaction engineering with the material balances and thermodynamics topics to more efficiently cover stoichiometric balances, chemical equilibria, and energy balances in nonisothermal reactors. The last topic covered is separations.

The level of mathematics was chosen to make the courses accessible to students having one year of calculus. Consequently, the courses focus on the development of differential equations used in chemical engineering analysis, rather than the mathematical methods used to solve the equations analytically. To avoid requiring a differential equations course, the differential equations encountered in the courses are either separable or are readily solved numerically or graphically. In some cases, students are provided with tools for solving differential equations. For example, Foundations in Chemical Engineering I includes a set of simultaneous differential equations for two parallel reactions involving six species. The set of equations is integrated using the fourth-order Runge-Kutta technique, and a spreadsheet is provided to execute the solution. An understanding of the concept of a partial derivative is required for both courses. Students are not asked to solve partial differential equations (PDEs) analytically, however. For instance, in Foundations in Chemical Engineering II, students use shell balances to derive unsteady-state conduction and diffusion equations—and then use graphical solutions to the resulting PDEs to do calculations involving unsteady-state heat and mass transfer.

CREATING A BRIDGING PROGRAM

While Foundations in Chemical Engineering I and II can provide the chemical engineering core of a bridging program, additional bridging courses may also be needed. At MSU, bridging students are also required to take the first semester of senior design and the controls course. Although students completing this bridging curriculum do not have the depth of chemical engineering knowledge equivalent to that of a BS degree student, we have found that their increased breadth of background offers advantages that more than compensate for the lack of depth in the bridging courses. The added value of the cross-training becomes particularly obvious when a bridging student is assigned to a research project at the interface of chemical engineering and the discipline of his or her BS degree. Moreover, we have found that integration of bridging students into our graduate program enriches the educational experiences of the traditional chemical engineering students with whom they interact.

The offering of the courses on an accelerated summer schedule is especially well suited for bridging purposes. It allows students who complete a BS degree in the spring to begin graduate coursework in chemical engineering in the fall. Thus, the time investment required for students to bridge is minimal. In contrast, schools without an intensive bridging program may require students to take one to two years of chemical engineering courses before starting graduate coursework, significantly extending the time required to graduate. The summer program also provides an independent assessment of a student's prospects for success in a chemical engineering graduate program. At MSU, acceptance of a bridging student into the graduate program is conditional upon achievement of a 3.5/4.0 in each course. More information on the MSU bridging program is available at <http://www.egr.msu.edu/che/cont.ed/>.

DELIVERY STRATEGIES

The use of information technology (IT) and multimedia has provided educators with a broad spectrum of tools that enhance student learning and diversify the types and locations of audiences to which technical courses may be offered. The evolution and effectiveness of these technology-enhanced learning environments have been recently reviewed by Edgar[1] and Kadiyala and Crynes.[2] IT and web-based instructional materials have been used at various levels of classroom integration. These levels range from the fairly straightforward posting of course information (office hours, homework assignments, course schedules, communications), to synchronous or asynchronous web tutorials and course supplements,[3,4,5] to virtual or full laboratory automation,[6,7,8] to complete and self-contained courses.[9,10,11]

We wanted the course lessons in Chemical Engineering I and II to incorporate a variety of synchronized, multimedia features—including text, graphics, sound, and the ability to annotate the text during the presentation with sketches and typed print. The tools used to develop the MSU bridging courses are discussed below, and URLs for the software are provided at <http://www.egr.msu.edu/che/cont.ed/resources/>. The software package Clipboard 2000 was used to prepare the course lessons. Clipboard 2000 is a multimedia presentation package that can create QuickTime movies consisting of synchronized slides, sound, camera image, mouse-directed pointer, drawing via an electronic tablet, and keyboard input.

Lessons typically consist of a series of detailed outline slides containing graphics that are explained sequentially by the instructor. The mouse pointer, drawing tablet, and/or keyboard are used extensively to annotate slides and direct the student's attention, much as a professor would do when making an overhead transparency presentation. To encourage participation in the form of note taking, we provide students with a partially completed version of each slide and encourage them to complete the slides while viewing the lessons. To facilitate other options for learning, we also provide a link to the completed slides. An example lesson illustrating the multimedia format is provided on the preview site for Foundations in Chemical Engineering I <http://vu.msu.edu/preview/che804/example/>.

Each course is divided into about fourteen topic areas, each of which consists of several lessons. The lessons range from about six to twenty minutes in length and are designed to be relatively short, self-contained "packets" of information. This approach helps students maintain concentration, allows busy students to view lessons during short blocks of free time, and minimizes technical problems arising from downloading large lessons. Each lesson has a set of clearly defined learning objectives and a checklist of expected proficiencies (outcomes) that should be gained by doing the lesson and associated homework. The objectives and proficiencies are intended to facilitate learning and to help students identify topics needing further study. During the lessons, students are prompted to stop the movie, answer a question or solve a problem, and then to restart the movie to check their answers.

The [two courses described here] were designed to prepare students with science and engineering degrees in disciplines other than chemical engineering for graduate training in chemical engineering—and to provide continuing-education certification in chemical engineering for industrial scientists and engineers.

A bulletin board program, "Web Talk" developed by the MSU Virtual University (http://vu.msu.edu) is used for questions and answers. The homework assignments provide natural categories for the posting of questions and answers. The Web Talk tool has the capability for uploading files and graphics, a feature that is helpful for communicating clearly. Other "listserv" tools could be as effective, provided that categories can be established to organize conversations in the various topics. The Web Talk tool provides a search option to locate all postings for specific keywords. Administrative capability is also provided, such as tracking posts from individual students.

The course web site also includes an electronic chat room that provides live group interaction among the students and the instructor. All entries are logged on the Web Talk for later reference. Students have commented that the chat logs are useful as review material. The most significant problem with the chat room is the difficulty in finding chat times that are suitable for all, because the participants live in different time zones and have different schedules.

Generally, there is one homework assignment per topic. Homework is due a few days after the scheduled completion of that topic. However, because not all students progress through the course at the same pace, we have implemented a system that allows students to view the solutions as soon as they submit their homework. Each student must post a query to get the web address of the solutions. The time of the query is logged automatically and can be compared to the time the student's solution was submitted by FAX. This system has helped assure integrity without intervention by the instructor, and it frees the instructor from distributing solutions at various times by FAX.

Six to seven open-book quizzes and a comprehensive final exam are administered during each course. The rigor of the exams is comparable to that found in a typical undergraduate course covering the same material. Each student designates a proctor (*e.g.*, a local librarian) to administer the exams. The proctors receive each quiz or exam by fax, allow the student the designated amount of time to solve it, and then fax the students' solutions back to the instructor. Grades for homework and quizzes are posted on the website.

COURSE PRODUCTION

The Clipboard 2000 production tool is freeware and runs on a MAC computer that costs less than $2,500. (Clipboard 2000 is also available on a PC platform. At the time of production, however, the PC version was less well-developed than the MAC version, so the MAC was chosen for our production). The only additional equipment required is a moderate quality microphone. Although Clipboard 2000 also offers synchronized video camera recording, we chose to not use the video camera to minimize bandwidth.

Slides for the Internet course were developed with assistance from undergraduate chemical engineering students who had recently covered the concepts in their own classes. Graphics are used extensively in the slides to illustrate concepts. These graphics were generally either computer-generated by the instructors or drawn by a professional artist. The Clipboard 2000 software requires the slides to have a "gif" format, which can be prepared on a PC platform from the PowerPoint97 html output option (not PowerPoint2000). The gif images created by PowerPoint, however, are not as sharp as the screen images that can be captured using a freeware program such as "!Glance." The gif image files are named sequentially for automatic incorporation into the final lesson by Clipboard 2000.

After the lesson is recorded, Clipboard 2000 combines and synchronizes all of the tracks and compresses the output to generate the final QuickTime movie. The QuickTime movies can be delivered to the students by streaming or by posting them in the "quick start" format. We use the quick start format because MSU does not currently support a QuickTime streaming server. The lessons play as downloading continues. A software glitch caused Quicktime 4.0 to underestimate the modem download time for longer lessons and to truncate the download at the estimated time. We overcame this problem by cutting the lessons into 5-7 minute segments that are loaded in succession automatically. This sequential delivery approach is transparent to modem users, who do not notice the transitions. The quick start format also permits caching of the movies for review. Local area network (LAN) users and cable users do not experience problems with longer lessons.

OBSERVATIONS AND RECOMMENDATIONS

As with classroom presentations, practice is required to produce organized, polished multimedia presentations. During the recording process, the instructor explains the material while operating the mouse pointer, pen and tablet, and keyboard, and also advancing the slides at the proper time. Coordination of all these activities can be challenging. Because Internet students can click the pause button or rewind to review portions of the lesson, pauses and repetition that may be effective in the classroom are unnecessary and distracting in Web lessons. Preparation of a written script with cues indicating when slides should be changed is helpful. The scripts can readily be edited to maintain consistency and to improve clarity when the lessons are revised at a later date.

Development of the course materials took more time than expected. For every hour of final recorded movie, about five to ten hours were required to prepare the scripts, graphics, and slides, record the lessons, review the movies, and then make corrections. Some lessons were recorded multiple times to achieve a more polished product. The short lesson times were a benefit for these steps.

The Internet platform seems better suited for the bridging courses than the satellite-broadcast platform. The satellite broadcasts offers the possibility of live interaction between the professor and remote students during lectures via a toll-free phone service. The students did not avail themselves of this opportunity, however. In fact, most of the remote students recorded the live broadcasts to view them at a more convenient time. Students without access to a satellite downlink were mailed videotapes of the lectures. Thus, the potential advantage of synchronous delivery via live satellite broadcast was rarely realized. On the other hand, the advantages of Internet delivery—instant delivery to students virtually anywhere and at any time, plus the ability to incorporate interactive features, spreadsheets, animations, bulletin boards, live chat rooms, etc.—have the potential to make distance learning both convenient and effective.

Overall, the courses ran smoothly during the first Internet offering. The most significant problem was with students falling behind. This problem is common with distance courses[12] (both satellite and Internet). Because of periodic administrative delays, travel, etc. the course calendar must often be adjusted by the instructor. In addition, the unpredictable schedules of the students, many of whom are non-traditional students with many time obligations, require some flexibility on the part of the instructor. We recommend identifying problems with time management as early as possible and strongly encouraging the students to stay on schedule. To assist in this regard, students are provided with clear guidelines for acceptable compliance with the course calendar.

To help the instructor respond to inquiries while out of the office, we find it helpful to prepare a course notebook containing the course calendar, homework solutions, and quiz statements and solutions. This notebook can be carried home and on trips, thus adding flexibility to the instructor's schedule while the course is ongoing. Written organization of reading and homework assignments was also found to be important, because we cover selected textbook sections rather than all material in the textbook.

ASSESSMENT OF THE FIRST INTERNET OFFERING

Student feedback on the first Internet offering of Foundations of Chemical Engineering I and II has been positive. Seventy-one percent of those completing the on-line survey said they would enthusiastically recommend the courses based on coverage and mastery of material. Even though only 29% rated the Internet courses as good or better than a standard lecture class, 71% thought that the convenience to their schedule or location outweighed the disadvantages. In response to the open-ended request for anonymous comments, one student responded

- *"I liked the fact that even though this was an Internet course, I still had a good amount of contact with the professor. The professor was always helpful and receptive to questions and comments. He was also very understanding."*

Regarding the bulletin board system posting of chat sessions another student wrote

- *"I think Webtalk is wonderful; recording the live chats was a tremendous help for me. Being in a different time zone made it hard for me to participate in the live chats and it was great to see the conversation after it took place! Several of my questions were answered this way."*

Based on the assessment results, improvements in the courses are now being implemented. Our goal is for the students to rate the Internet offerings as being at least as effective as a conventional lecture course. Dutton *et al.*[12] have analyzed student performance for a computer science course offered both as a traditional lecture and for online and certificate (continuing education) students. Their analysis shows that on-line students who complete a course generally did significantly better than lecture students. Continuing education students, however, had a lower likelihood of completing a course than students enrolled in a traditional lecture. This finding, plus our own observation that Internet students find it difficult to remain on schedule, suggest that we should emphasize and encourage time management during future offerings.

SUMMARY

A two-course sequence has been developed to teach chemical engineering fundamentals to students having degrees in science and engineering fields related to chemical engineering. The courses were developed specifically for Internet delivery, and employ a multimedia format that includes synchronized slides, voice, pointer, keyboard, and pen input. The Internet-delivery format allows broad access to virtually all students, regardless of location or schedule. The courses were designed to prepare students with science and engineering degrees in disciplines other than chemical engineering for graduate training in chemical engineering—and to provide continuing-education certification in chemical engineering for industrial scientists and engineers. Such training can help meet industry's growing need for employees who are cross-trained in science and chemical engineering.

REFERENCES

1. Kadiyala, M., and B. L. Crynes, "A Review of Literature on Effectiveness of Use of Information Technology in Education," *J. Eng. Ed.*, **89**(2), 167 (2000)
2. Edgar, T.F., "Information Technology and ChE Education," *Chem. Eng. Ed.*, **34**(4), 290 (2000)
3. Burleson, W., A. Ganz, and I. Harris, "Educational Innovations in Multimedia Systems," *J. Eng. Ed.*, **90**(1), 21 (2001)
4. Smith,W.R., I. Sikaneta, and R. W. Missen, "The Interactive Java-Based Web Site for Teaching Chemical Reaction Stoichiometry," *Proc. 1999 ASEE Annual Conference & Exposition*, Charlotte, NC, June 20-23 (1999)
5. Graham, C.R. and T. N. Trick, "Java Applets Enhance Learning in a Freshman ECE Course," *J. Eng. Ed.*, **87**(4), 391 (1998)
6. Henry, J., "Laboratory Remote Operation: Features and Opportunities," *Proc. 2001 ASEE Annual Conference & Exposition*, Albuquerque, NM, June 24-27 (2001)
7. Mannix, M., "The Virtues of Virtual Labs," *PRISM*, **10**(1), 39 (2000)
8. Gillet, D., H.A. Latchman, C. Salzmann, and O.D. Crisalle, "Hands-On Laboratory Experiments in Flexible and Distance Learning," *J. Eng. Ed.*, **90**(2), 187 (2001)
9. Holman, W.T., "Creating Simple and Effective Prerecorded Web-Based Lectures," *J. Eng. Ed.*, **88** (3), 261 (1999)
10. Crynes, B.L., Y.K. Lai, and W.S. Chung, "Chemical Engineering Fundamentals—Better Learning Through Web-Based Delivery," *Proc. 1999 ASEE Annual Conference & Exposition*, Charlotte, NC, June 20-23 (1999)
11. Scranton, A.B., R.M. Russell, N. Basker, J.L.P. Jessop, and L. C. Scranton, "Teaching Material and Energy Balances on the Internet," *Proc. 1999 ASEE Annual Conference & Exposition*, Charlotte, NC, June 20-23 (1999)
12. Dutton, J., M. Dutton, and J. Perry, "Do Online Students Perform as Well as Lecture Students?" *J. Eng. Ed.*, **90**(1), 131 (2001) ❐