Graduate Bridging and Continuing Education in ChE via the Web

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Abstract

The cross-disciplinary nature of chemical engineering principles makes education in this field increasingly relevant for working professionals. In addition, students with bachelors' degrees in other disciplines are progressively more interested in obtaining advanced degrees in chemical engineering. To address these multiple purposes, Michigan State University provides two three-credit semester Internet courses that deliver foundational concepts in chemical engineering principles to multiple audiences. "Foundations in Chemical Engineering I and II" (http://www.egr.msu.edu/che/cont.ed) offer content that has been developed at MSU over the last 20 years to "bridge" students from other disciplines into the chemical engineering graduate curriculum. The course purpose has expanded to include the continuing education needs of technical professionals; therefore, the Internet courses are delivered with options for lifelong learning or for advancement into graduate studies. Our presentation will discuss the strategies used to select course content and the delivery techniques used in these web-based courses. We will present perspectives and recommendations from our experiences in using this medium for effective instruction of students.

Introduction

It is becoming increasingly common for students from chemistry, biology, and other physical sciences to be interested in graduate work in chemical engineering. Such training answers a pervasive need in research and industry for professionals with cross-disciplinary education. At Michigan State University (MSU), we have found that the integration of these students into our graduate program enriches the experiences of our traditional chemical engineering students. In addition, the key concepts from the chemical engineering undergraduate curriculum serve as excellent material for continuing education for engineers and scientists in other disciplines. The MSU courses serve these purposes in the following ways:

Certificate Program: The courses provide professionals from other science and engineering disciplines an overview of fundamentals of chemical engineering. The two courses include most of the foundational principles covered in the four-year chemical engineering curriculum. Environmental engineers, chemists, biochemists, mechanical engineers, agricultural engineers, and food scientists are some of the professionals that have taken these courses to enhance their own technical backgrounds. This certificate version of the course is offered by our department through the MSU Office of Instructional Outreach. A *Certificate of Achievement in Foundations of Chemical Engineering* is awarded for each course upon satisfactory completion. Although the

basic course material is the same as for the Bridging Program (please see below), the requirements for completion of the courses for a certificate are somewhat different than completion of the courses for credit and a grade.

Bridging Program: The courses offer a "Bridging Program" into a chemical engineering M.S. or Ph.D. degree program for B.S. students with non-chemical engineering degrees. The courses provide enough background that students can enter and *successfully* complete graduate chemical engineering degrees. In addition to these courses, we require completion of the undergraduate courses *Process Design and Optimization I* and *Process Systems Control*. We find that students completing this bridge curriculum have sufficient background to enter our graduate courses even though the extent of their chemical engineering background might not be considered equivalent to a B.S. degree student.

Historical Perspective

The course material has been packaged as a bridging program at MSU for over 20 years. The courses were originally developed to attract high-caliber chemists into our graduate program. Historically, the courses were offered in the summer semester and were team-taught by three to four faculty members. The courses were originally developed when the MSU graduate program was smaller and not as well-recognized, but the courses continue as an important component of the graduate program.

The two courses were historically taught on-campus over the fifteen week summer semester. With the addition of Web offerings, they are currently offered in the Fall (Foundations I) and Spring (Foundations II) as well as during the summer (Foundations I and II in sequence). The courses are homework-intensive and focus on developing problem solving skills using chemical engineering principles. Twenty-four students entered our M.S. program via the bridge program over a recent period of nine years. Of these students, 16 became M.S. students (some of our current M.S. students may continue for a Ph.D.), three became Ph.D. students, and five discontinued after the bridge course. Those who completed the subsequent required collateral course, *Process Design and Optimization I*, received an average grade of 3.56. For the bridging students continuing in the graduate program, their average *graduate* GPA was 3.68. Based on these gradepoint averages, we have concluded that the bridge program is successful in providing the fundamentals necessary for strong performance at the graduate level.

In the mid 90's, the courses were offered via satellite through the National Technological University (NTU), which increased the availability of the courses to those sites with the satellite downlinks. Based on these experiences as a solid track record for these courses, in 2000 and 2001, we have redesigned the course presentation for a Web format, thus increasing the potential audience. NTU continues to use the courses for bridging their students into their online graduate program. The new Web offering consists of two 3-credit semester courses, Foundations in Chemical Engineering I and II. Additional information on the course philosophy is available at www.egr.msu.edu/che/cont.ed.

Course Structure

The objectives for selection of material for the two courses 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), or basic dimensionless correlations (friction factor, heat and mass transfer coefficients). Since the goal of the courses is to develop applied problem solving skills, a minimum of derivations is expected, and most problems focus on applications. The courses intentionally cover only a minimum of special or novel topics; these more specialized areas can be acquired by the students through independent study.

The courses are packaged to contain material that is largely interdependent, and the topics are taught with some variation from the chronological order of a conventional curriculum. For example, students would normally take reaction engineering after the separations course in the standard curriculum, but we have integrated it with the material balances and thermodynamics to more tightly integrate coverage of stoichiometric balances, chemical equilibria, and energy balances in non-isothermal reactors.

Foundations in Chemical Engineering I includes content from 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; the energy balance; the 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 laws; 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; and nonisothermal reacting systems. A course overview with an entire lesson list is available at http://vu.msu.edu/preview/che804.

Foundations in Chemical Engineering II includes material covered in our courses on fluid flow and heat transfer, and mass transfer and separations. Topics include dimensional analysis; an 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; and liquid-liquid extraction. A course overview with an entire lesson list is available at http://vu.msu.edu/preview/che805.

Delivery Strategies

Delivery via the Web offers new opportunities as well as new challenges. One of the challenges is to communicate effectively to students who may represent a range of learning styles. We have regarded the concept of note-taking to be an important element of the learning process; therefore, we have developed lessons that start with partially prepared slides that students download and

print out. They complete their slides by watching the lessons and taking notes when the information appears on the screen in synchronization with the audio track. To facilitate other options for learning, we also provide a link to the complete slides.

The main topics in each course are delivered in lessons that range from 6 to 20 minutes in length. Lessons are deliberately designed to be relatively short "packets" of information, and are not as long as typical classroom lectures. The rationale for this approach is to attempt to optimize student attention, to provide convenience for the working student, and to minimize potential problems with downloading the lessons. Each lesson has a set of clearly defined learning objectives and a checklist of expected proficiencies (outcomes) that should be gained after the student has studied the lesson material. These are intended to facilitate learning for the busy student and to help students focus on material in which they are weak. During the lessons students are prompted to stop the lessons to work out answers to questions and then to click the play button to find the answer.

For production and delivery of the course lessons, we have chosen to use a tool known as "Clipboard2000" (http://um-captest.ummu.umich.edu/cb2k/). A pointer feature is used during recording to direct the student's attention much as would be done by an instructor using a pointer in a classroom. Clipboard2000 also permits typing on the slide (arial font only) and crude sketching in various colors. Special graphics have been included in the slides to more clearly illustrate the more difficult or more visual concepts. An example lesson illustrating the format is provided from a link on the preview site for Foundations in Chemical Engineering I (http://vu.msu.edu/preview/che804/).

Each courses is divided into about 12 topic areas, with several lessons in each topic. Each topic has a homework assignment. A bulletin board program, "Web Talk" developed by the MSU Virtual University (vu.msu.edu - see also http://ffccreal.cl.msu.edu/ffcc/vuoverview.shtml) is used for questions and answers; the homework assignments provide natural categories for posting of questions and answers. The Web Talk tool has the capability for uploading files and graphics, a capability 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 keyword(s). Administrative capability is also provided such as tracking posts from individual students.
The course web site also includes a chat room that provides live group interaction among the students and teacher. For those students who do not chat, the sessions are logged on the Web Talk. Students have commented on how the chat logs are useful for review of material. Even the students who are in the chat room use the logs to review the discussions. The most significant problem with the chat room is the difficulty in finding suitable chat times when the participants have different schedules and live in different time zones. Chat sessions are typically held at 9 pm Eastern time for 1 hour on selected weeks, typically at a point when students encounter a new topic and begin the homework. While this time is convenient for most students, other are occasionally unable to participate.

Students are required to submit homework solutions on a regular schedule. Frequently for web-based or satellite courses, the scheduling of homework submission and posting of solutions is problematic. Our approach is to post homework solutions on the web prior to the due date;

however each student must post a query to get the web address of the solutions. Students are required to submit their solutions by FAX prior to posting a query for the solutions. The time of the query is logged automatically and can be compared to the submission time of the homework. This system has helped assure integrity without intervention from the instructor; the students can access solutions when the problems are still fresh in their minds. The system also frees the instructor from distributing solutions at various times or by FAX.

In addition to the final exam, seven quizzes are administered during the semester. Each student designates a proctor, who may be an office supervisor, local librarian, etc. The only restrictions are that the proctor cannot be related or a subordinate employee. The proctors receive the quizzes and final exam by FAX, and they administer the material for the student. The quizzes and final exam are open book, closed notes. The proctor returns the completed material to the instructor by FAX. Grades for homework and quizzes are posted on the website.

Course Production

The Clipboard2000 production tool is freeware and runs on a MAC that is available for less than $2500. The only additional equipment required is a moderate quality microphone. (Clipboard2000 is also available on a PC platform, but the development lags behind the MAC platform, so a MAC was chosen for our production). Clipboard2000 offers simultaneous video and audio recording; we have chosen to not use the video camera option to minimize bandwidth.

The lessons consist of the slides with accompanying audio. Slides for production are required in the *.gif format, and can be prepared on a PC platform from the PowerPoint97 html output option (*not* PowerPoint2000) with some loss in quality of graphic (gif) images. Alternatively, the slides can be created in higher quality by capturing screen images using a freeware program such as “!Glance” (http://www.zdnet.com/downloads/stories/info/0,,0018IP,.html) that requires individual naming of the images as they are saved. The Virtual University staff uses the !Glance program, and we sometimes use the PowerPoint option for lessons that don’t have detailed graphics. The graphics are combined with audio and synchronized by reading a prepared script. Clipboard 2000 compresses the presentation into a QuickTime movie.

Clear channels of communication are necessary for working with any web production. Although the Virtual University provides personnel to assist in slide preparation, they typically have little technical knowledge of chemical engineering, and are unable to proofread the slides effectively. We have hired chemical engineering undergraduate students for slide preparation with successful results.

The use of a script when recording the lessons is helpful. The preparation of the Clipboard2000 lessons is significantly different from delivery in a classroom, and pauses that are normally effective in the classroom are distracting on the Web lessons. Internet students can always click the pause button, or review portions of the lessons by scrolling backwards, so the audio also must be error free to maintain high quality. Scripts are also extremely helpful in responding to student questions. The scripts make it easy to review how concepts were actually described, or if important details are inadvertently omitted from lessons. Clarification can then be posted.

Organizing the course material into topics and lessons facilitates delivery of the course. For example Foundations in Chemical Engineering I comprises 16 topics. Each topic is subdivided into approximately seven to ten lessons. The lessons in QuickTime format can be delivered by streaming or by posting 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. Because of a software glitch, we found it necessary to cut lessons into 5-7 minute segments that are loaded in succession automatically. The cutting is necessary since QuickTime currently underestimates the modem download time for longer lessons and truncates the download at the estimated time. Despite these current shortcomings, modem users experience no delivery problems using the segmented delivery. The quick start format also permits caching of the movies for review. LAN users and cable users did not experience problems with longer lessons, but we have only posted lessons in the segmented format to accommodate modem users.

Recommendations for Working with Students

Overall, the courses have run smoothly. The most significant problem has been with students falling behind in the course. This is a universal problem both with satellite and web delivery and not unique with the web-based courses. Time management is stressed to the students; however, some students are working full time, and are overburdened with the workload in the course. These problems are best identified early in the course and require intervention from the instructor. Weekly monitoring of the progress is recommended, as well as some penalty for materials submitted more than a week past the due date. Some flexibility in due dates is necessary to accommodate the unpredictable schedules of nonconventional students who may be working full time. These penalties and restrictions do not apply to the certificate students who have a lighter course workload and more flexible schedule.

Instructors should prepare a course notebook containing printouts of the course calendar, homework solutions, quiz statements and solutions. The course instructor should carry this and the relevant textbooks home in order to be able to answer e-mail postings in the evenings or questions during chat sessions.

Written course organization is extremely important. An Internet course must be more structured than a lecture course with the same material. As described above, we provide specific learning objectives and proficiency checklists for each topic to identify the most important concepts. Written organization is also extremely important for these courses because we use selected textbook sections rather than covering all material in the textbook chapters.

Even though the courses are in their first offering, feedback from students has been generally positive. Both on campus and distance students use the Internet format. Distance students appreciate the ability to work and study at any time of the day from their "home" location. This convenience, coupled with the availability of Internet access, makes graduate bridging and continuing education in the fundamentals of chemical engineering accessible to a broad audience.

Summary

The Internet can be used to effectively deliver course content. Preparation of the slides and scripts is very time-consuming and the effort should not be underestimated. Html or pdf files must be prepared for homework solutions, and must be organized for posting. Despite the significant effort required in course development and start-up, it is expected that in subsequent course offerings revisions will be minor, and will require significantly less effort compared to subsequent offerings of a typical on-campus lecture course. In considering the funding of the production of this course, MSU administration considered the strong potential for continuing education as well as the bridging opportunities as factors supporting the revision of these courses for the Web. In addition, the unique nature of the courses and the potential to serve other chemical engineering departments were key factors. The increasing availability of the Internet assures that it will be used for education into the future. As engineering educators, we need to constantly consider how we can use the medium most effectively, and how to best integrate learning and teaching strategies.

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