Heat Transfer On-Line

William B. Baratuci, Angela R. Linse
University of Washington
Department of Chemical Engineering /
Center for Engineering Learning and Teaching

Introduction

This paper describes a project in which the internet was used to deliver a core course in the Department of Chemical Engineering at the University of Washington (UW). This web-based distance-learning section of Transport Processes II, commonly known as "heat transfer," was offered in Spring 2001. The distance-learning section allowed students to participate in the College of Engineering Co-op Program without falling behind in the sequence of required chemical engineering courses. Baratuci designed the courseware for delivery of content on the web, called Heat Transfer On-Line (HTOL), and taught the course in its initial offering. Baratuci and a team of undergraduate students created the content for HTOL.

We first discuss the curricular context of the course. We then describe its unique technological characteristics. Next, we outline the procedure for collecting assessment data from the students and then present the results. In the final section of the paper, we present our thoughts about this course and distance learning in general and look ahead to the next time this course will be offered.

Project Objective

The UW College of Engineering funded development of a series of distance-learning courses to support its Engineering Co-op Program and make it easier for chemical engineers to participate. Students, potential employers, and our faculty agree that co-op can be a valuable part of an engineer's education. Students may accept a summer-only assignment or they may extend their time-to-degree by working on a co-op assignment during the academic year.

The HTOL course was designed to resolve the problem that few students in the Department of Chemical Engineering participated in the engineering co-op program because it hindered progress through the department's curriculum. Some required courses are offered only once per academic year. Students who are unable to enroll in a required course during the quarter in which it is offered, must delay graduation by one full year. As a result, there is a strong disincentive for Chemical Engineering undergraduates to participate in the co-op program in any quarter other than Summer.

Heat transfer was the first course selected for our new distance-learning program because it is the only course required for Chemical Engineering juniors in Spring Quarter. By offering this course at a distance, students could work a Spring or Spring-Summer co-op assignment without delaying graduation for a full year. The Co-op students enrolled in the course were both on Spring-Summer assignments.

Course Goals and Students

An overall goal of the course was to provide comparable learning experiences for distance and on-campus students. The courses are not identical, but the students must be well prepared to meet the challenges of subsequent coursework. Thus, for comparative purposes, we decided to offer the course during the same quarter and use the same textbook[1] as the on-campus course. In the future, the course may be offered in other quarters as well.

While the success of any educational endeavor depends on students' motivation, the importance of motivation is critical in a distance-learning course because of the limitations on student-instructor and student-student interaction. Flori[2] lists six types of interaction that characterize an expert teacher that he quoted from Collins, Brown and Newman.

- Modeling: Showing how and why an expert does a task.
- Coaching: Observing students as they work and correcting their performance online.
- Inquiry: A strategy of questioning.
- Articulation: Getting students to articulate their own knowledge and reasoning.
- Reflection: Replaying and abstracting students' work and contrasting that with expert performance.
- Exploration: Pushing students into a mode of trying to do the activity better on their own.

Flori[2] observes that the last five types of interaction on this list are particularly difficult to implement in computer software. Without regular face-to-face interaction, some of the responsibility for initiating these interactions shifts from the instructor to the students. This requires more discipline, responsibility, and effective time-management on the part of the students. Consequently, the effect on student motivation was a major consideration in every design choice in the development of the course.

Students in the heat transfer distance-learning section were highly motivated because this course allows them to progress through the Chemical Engineering curriculum at the same rate as their peers on-campus. This means that their graduation will only be delayed by one quarter instead of a full year. Students in the Spring 2001 offering of the HTOL course were particularly motivated because they enrolled in the course despite forewarnings about potential difficulties associated with this new distance-learning course.

<u>Students</u>

The number of students enrolled in the initial offering of this course was small; it included two co-op students and four on-campus students. If the course continues, enrollment is expected to increase as more students become aware of the course and the flexibility it offers. In future years, students will be aware of this option early in their junior year and more will be able to consider participating in co-op without hindering their progress through the program.

The presence of on-campus students changed the nature of the course because four of the six students were able to interact with each other face-to-face. However, it was impossible to justify offering a course for just two students. The on-campus students took the course for a variety of reasons such as it was more convenient to their schedules and the visual content and ability to hear the lectures more than once was a better match for their learning needs than a standard lecture course.

Course Design and Delivery

Many authors have reported on their experiences developing and using computer-based training materials[3,4], web-based training materials[5] and CD-web hybrid training materials[6].

Computer-Based Training Courses

Computer Based Training (CBT) was the obvious solution to the Chemical Engineering Department's limitations for co-op participants and provides opportunities to incorporate up-to-date pedagogical approaches with modern technology. CBT courses incorporate a high level of student involvement and responsibility that is not easily matched in the classroom. Part of that involvement can be attributed to the ability of the student to tailor the course to her specific needs. Many studies indicate that distance students perform as well, or even better, than their peers in traditional on-campus courses [7-10]. A student can progress through a lesson at her own pace, review material at any time, peruse example problems at her own discretion, and take the end-of-lesson quiz and receive immediate feedback.

CBT courses can also provide a balance of verbal and visual information to accommodate different learning styles. We included video segments of the course instructor in the HTOL program because they remind students that they are enrolled in a real course with a real instructor who is concerned about their learning experiences and success.

The attributes of CBT help keep students focused and motivated, as long as they are running the program. The challenge is to ensure that students spend enough time using the program to succeed in the course. This is where use of the internet offers certain advantages over CBT.

Web-Based Training

We decided to make the HTOL courseware available via the world wide web. Web-based training (WBT) has both advantages and disadvantages. Some of the advantages include:

- WBT does not require physical distribution of courseware;
- Courseware is relatively easy to maintain and update because it resides on a single server;
- Access to course material on a website is relatively easy to restrict and eliminates the need to develop or purchase a copy-protection scheme for physically distributed software.
- WBT permits instructors to track the progress of individual students through the course. This provides instructors with the opportunity to interact with and encourage students, praising superior progress and providing support for students who need help.

The primary disadvantage of WBT is the slow rate at which data are transferred from the server to the student's computer screen. Information on a CD or hard disk can be displayed many times faster than information can be transmitted through the internet, particularly if students access the internet through standard phone line. Since our primary target audience is a group of co-op students, typically living in temporary housing, we had to accommodate the limitations of standard 56 kbps phone line access. The quality of streaming video at that data rate is not impressive, so we provided each student with a CD that contained the video content. Thus the HTOL courseware is a CD-Web hybrid.

We not only used the internet to deliver content, we also used it to encourage student-student and student-instructor interaction. Common educational uses of the internet include:

- email, including anonymous email,
- bulletin boards,
- threaded discussion boards,
- automatic mailing list servers, and
- chat rooms, possibly including real-time video.

Each of these technologies improves communication with the instructor as well as with other students. Improved communication can boost the motivation level of distance learners by promoting a sense of connectedness. Increasing the feeling of connectedness that the student experiences may improve her motivation and increase the amount of time she spends using the courseware. Unfortunately, email is the only technology on the list that is uniformly available to faculty members.

The computing organizations at many universities, including the University of Washington, can help faculty set up any or all of the technologies on the above list. We elected to use email, anonymous email and a threaded discussion board in the first offering of the course. The threaded discussion board served the function of both the bulletin board and the automatic mailing list server. Chat room technology was not readily available at the time the course was first offered. Real-time video would have been problematic due to the bandwidth limitations noted above.

Once these broad design choices were made, the program to implement the design was constructed. The program we would use to deliver our course was christened Heat Transfer On-Line and the acronym HTOL was adopted.

Software Development Tools

Most of the software tools that we elected to use are part of the Macromedia suite, including Dreamweaver, Flash and Authorware. Flash, was used to develop the animations for HTOL. The heart of HTOL was developed in the multimedia authoring tool called Authorware. Authorware provides an environment in which text, graphics, video and sound can be integrated and organized for consistent presentation to students. It provides a level of interactivity, structure and record keeping capabilities that are very difficult to produce in a website that only uses HTML. Figures 1 through 4 display screens captured from HTOL. They are included at the end of this paper so that the reader can get a feel for the nature of the user interface.

The drawback to using Authorware to build a WBT program such as HTOL is that a browser plug-in is required in order to view the software modules. Fortunately, the plug-in can be downloaded for free and installation of the plug-in did not present a problem for any of our students.

We used Dreamweaver to build the website that coordinates access to the heat transfer content as well as the interaction tools. The interaction tools, including a threaded discussion board and an anonymous email tool, were created by the Catalyst organization at the University of Washington (http://catalyst.washington.edu/). Catalyst is sponsored by UWired, a collaborative project to encourage the use of technology to enhance teaching and learning. The Catalyst

program provides resources and tools to help instructors teach with new technologies. HTOL made use of the Catalyst Web Tools designed to facilitate student-student and student-faculty interaction.

Several other programs were also used to develop HTOL. The audio clips were edited with Sound Forge XP from Sonic Foundry. Microsoft Word was used extensively for content development, including simple graphics. Adobe Photoshop was used for more sophisticated image preparation and manipulation. Adobe Acrobat was used to prepare compact PDF documents for the students to download. Adobe Premiere was used to edit and compress video clips. Finally, Microsoft Excel was used to solve all example and quiz problems and to present the calculations in a well-organized form.

Course Structure and Mechanics

This distance-learning course had an organization similar to an on-campus course. The HTOL course content was organized into ten chapters that correspond to the chapters in the textbook[1]. Each chapter was subdivided into 5-10 lessons.

The first lesson of each chapter includes a 4-7 minute video clip of the instructor introducing the topic. The video clips help students put each chapter into context within the course and engineering practice. The introduction typically includes background or historical information, applications relevant to the chapter and insight about how the chapter relates to other course material.

Subsequent lessons for each chapter had a consistent organization. Each lesson begins with a series of screens, or pages, of content followed by one or more example problems. A one-page summary of the lesson follows the examples. Each lesson ends with an optional quiz on the lesson material. See Figures 2 through 4 for screens captured from HTOL.

A typical page of content consists of a graphic, a few equations, a few sentences of text and one to four audio buttons. Reading from the screen is limited. Each button plays a short explanation or discussion of a portion of the information displayed on the page. Each lesson contains approximately twenty-five minutes of audio and seven lessons were covered in a typical week. The total time a distance student spent listening to audio in HTOL approaches the amount of time an on-campus student would spend in lectures. The audio clips recreate some aspects of a traditional lecture course. However, other attributes of the course provide students with more opportunities to be interactive and engaged than students in on-campus lecture courses.

The example problems illustrate the specific topic discussed in each lesson and provide detailed solutions to typical problems. The undergraduate Chemical Engineering students who worked on this project developed the problems. Example problems include graphics, text, and equations and vary from 5-10 pages in length. With nearly 60 example problems, HTOL students may have been exposed to more example problems than their on-campus peers.

The purpose of the HTOL quizzes was to provide quantitative feedback to students regarding their performance and to allow the instructor to track the progress of distance students. The quizzes were scored, but the scores were not included in the students' grades.

A typical quiz includes of 2-4 questions and one or two calculation problems. The questions are framed to evaluate knowledge, recall, and comprehension of the material using multiple choice, true/false, or drag-and-drop question formats. If a student selects an incorrect answer, they are provided with the correct answer and a brief explanation. The calculation problems are comparable, in both length and difficulty, to the example and homework problems. In quiz problems, the student determines the values of a series of intermediate results that lead to the problem solution. Each intermediate result is evaluated and the correct answer provided so that the student can correct her work and continue working the problem. At the end of the problem, students may view a complete and detailed solution.

Tracking Student Progress

It is fairly easy to record the progress of a student through this course. HTOL allows the student to review her own progress file at any time. At the end of each session, the student's progress file is updated and transmitted to the server. The directory in which student progress files were stored was secure. This system allowed the instructor to review an up-to-date report on the progress of each student by downloading the appropriate progress file.

We used Authorware's FTP function to download a text file containing information about each student's progress at the start of each session. The student progress file contains basic identification information plus a few measures of student progress. The file indicates the percentage of pages accessed in each lesson. When a student accesses her progress file, she is reminded of the pace set by the instructor for the course so that she can accurately assess her own progress. The file also provides the total time the student ran the progam, which may be useful for comparison purposes. While neither measure is a direct indication of student progress, low values might indicate the need for the instructor to intervene.

The progress file also provides the score that the student earned the first time she took the quiz at the end of each lesson. This measure can indicate whether a student has fallen behind, but it can also give some indication of how much the student learned the first time she ran through each lesson. Trends can help the instructor determine the point in the course at which the student became confused. Trends can also help identify lessons in HTOL that need improvement.

Program Features

If a student feels lost while navigating through a piece of courseware, the level of frustration will rise and the level of motivation will fall. Several measures were taken in order to help students find their way through HTOL. Each page includes a display panel that indicates the chapter, lesson, page number, total number of pages, and elapsed time in the current HTOL session. A "Send Email" button encourages email interaction during the lesson. Clicking the email button launches an internal email routine, which appends the chapter, lesson, and page number to the email subject. See a typical page from an HTOL lesson in Figure 2.

Navigation buttons, provided on each page, allow users to move forward or back one page or to jump to the first or last page of the current lesson. Context sensitive pull-down menus allow a student to move around within a particular lesson by jumping directly to a specific page, to return to the beginning of the lesson, or to jump to a menu page with a more extensive list of options. The navigation and "Send Email" button are also available for the example problems.

Several options were available for the students to interact with each other and with the instructor. All of the students who were willing, exchanged telephone numbers and email addresses and the instructor's phone number and email address were provided. Some face-to-face interaction was possible for students working in the Seattle area. A threaded discussion board was created for this course as well. Discussion threads were organized by chapter. The students and the instructor could post questions, answers or comments to the discussion thread associated with the appropriate chapter. The comments and questions posted to the threaded discussion as well as the responses from other students and the instructor could provide a searchable database for future student reference.

Course Assessment

This course was assessed in two primary ways, through student performance and student feedback about the course. The courseware permitted the instructor (Baratuci) to track student progress and performance. At the end of the course, rather than requesting that students fill out the standard student ratings questionnaire, an instructional consultant (Linse) conducted a class interview.

Student Performance Assessment

There were eight homework assignments, three tests and a final exam. Three tests were given to provide frequent deadlines to help the students keep up with the pace of the course. Homework assignments were turned in electronically as scanned documents or by FAX. Tests and the final exam were proctored and delivered to the instructor by email. Proctors were generally the co-op students' supervisor or mentor on the job. The proctors returned the completed exams by FAX. Graded homework, tests and exams were returned electronically whenever possible.

Overall, the students met the learning goals for the course. The average grade for the five chemical engineering undergraduates in the course was 3.43 (on a 4-point scale). This is comparable to their average grade in a previous chemical engineering course 3.2. Conclusive statements about student achievement in HTOL compared to the on-campus course are not possible because of the small number of students enrolled in the on-line course. As might be expected from highly motivated students, the average grades in the HTOL course were slightly higher (3.5 for co-op students, 3.4 for regular students) than the average grade of the on-campus heat transfer course (3.0). The average grade that the on-campus students had received in prior engineering courses was not available. To find out if these differences are significant, we would need to conduct a statistical test that takes into account the sample size and variability in student grades. A more direct performance assessment of the HTOL students' learning will be their performance in senior chemical engineering courses during the following academic year.

End-of-Course Assessment

Baratuci requested help gathering data from students about their perspective on the course. Linse, instructional consultant for the Center for Engineering Learning and Teaching at the UW, conducted a class interview on the last day of the academic term. All students voluntarily participated in the class interview (one student participated via speakerphone). Linse reiterated that the process was voluntary, that all individual student comments would be kept anonymous, and that the purpose was to help improve the course and student learning through constructive feedback.

The end-of-term assessment was modeled after the mid-quarter class interview, also known as the Small Group Instructional Diagnosis [11] (SGID). SGIDs use class interviews with students to gather suggestions to strengthen the course, increase communication between the students and the instructor, and improve teaching and learning [12]. The process identifies not only areas for change, but also ways to address those areas. While the method is typically conducted at midterm, so that students have the opportunity to impact the remainder of the course, it can also be helpful at the end of the term.

The primary benefits of this procedure over traditional individual student ratings are that students have the opportunity to 1) hear what other students think about the course, 2) clarify and acknowledge what they gained from the course, and 3) make a positive contribution to future students' learning, by using their experiences to improve the course.

The HTOL students were divided into two small groups and asked to write answers to the following questions:

- What helped you learn in this course? Please explain or provide specific examples.
- What changes would make the course more helpful? Please suggest specific ways to alter the course.

The two groups worked together for about 5 minutes on each question. Then the class participated in a whole class discussion; the out-of-town student answered the questions individually, then contributed to the whole-class discussion. As the students reported their answers, Linse created a master list of strengths and suggestions for change. After the interview, the comments were divided into themes based on both the intensity and frequency of the students' comments and reported to Baratuci.

What Helps Students Learn in HTOL

The six most important aspects of the course that students found helped them to learn include, in rank order: 1) homework, particularly the hints and partial answers that indicate whether students are "on track;" 2) grading and feedback; 3) quizzes; and 4) lectures available on-line; 5) examples; and 6) instructor accessibility. Nearly all of the students' explanatory comments focused on the interactive aspects and timeliness of all six items, i.e. how useful feedback, benchmarks, checks for understanding, all of which directly or indirectly are based on frequent interaction with the instructor. These themes are not surprising given what we know about good instructional practice [13,14]. However, the value the students assigned to the quizzes as tools for applying information presented in the lessons and text surprised Baratuci. Students predictably appreciated all of the additional example problems in HTOL, but the step-by-step nature of the solutions helped them integrate and apply the theory and equations they learned in the lesson.

Student Suggestions to Improve the Course

The students identified four areas for change in the course. These include, in rank order: 1) time-commitment, 2) benchmarking/tracking, 3) exams, 4) technological issues. Students need help managing the time that they spent on the course, which they perceived as much greater than required by on-campus courses. Students wanted more individual and group feedback about their progress and their cumulative grade. Students were frustrated when the progress/records feature of HTOL failed to function properly. Unfortunately, this problem could not be corrected

during the term. Once this was made clear to the students, they accepted it, but they felt they had lost a very important feature of the program.

With one exception, comments on the exams focused on activities that would help students prepare for the exams. The only recommendation related to the web-based instruction was to change how the exams are proctored so that all students have an opportunity to ask questions during the exam. While students accepted that many of the technological problems were beyond the control of the instructor, the fact that they brought them up in the class interview indicates that resolution of the issues is a priority for students.

The students concluded the exit interview with a discussion of the strengths and challenges of the distance-learning program at the University of Washington. Strong support for the co-op program translated into strong support for distance-learning. In hindsight, the students acknowledged that distance-learning requires more self-discipline and motivation than an on-campus class and observed that it was probably not for everyone.

Author's Perspective

The technical difficulties that we experienced with the record keeping function in HTOL had a significant impact on the students' learning experience. The exit interview only confirmed this fact. The program will be more robust in the Spring of 2002.

The students did not like the threaded discussion board. They strongly preferred to interact with the instructor via email. It is not entirely clear why, but the lack of anonymity when posting messages to the discussion board is believed to be the problem. It is not clear whether this can be resolved before the Spring of 2002.

Although everyone involved with the course considered HTOL to be a success, it should not be considered as a substitute for face-to-face instruction. Programs such as this one do not threaten the existence of the university, they only facilitate the exchange of ideas in flexible, convenient ways. Flori [2] quotes Laurillard: "Teaching is a rhetorical activity which seeks to persuade students to change the way they perceive and experience the world." Our instructional software has a long way to go in order to surpass the effectiveness of an excellent classroom teacher in this regard. Nonetheless, distance courses provide learning opportunities for students who cannot participate in traditional courses, for whatever reasons.

On a different note, it is difficult to ignore the similarities between distance-learning and life-long learning. In each, the learner must have a high level of self-discipline and motivation to succeed. There is limited peer-to-peer interaction in either case. In distance-learning, there is limited access to the instructor, while in life-long learning there generally is no instructor. There is a great deal of debate about how to encourage students to become life-long learners. Perhaps one way to do so is to let them practice the skills they will need later in life by taking a distance-learning course if they choose to do so.

Looking Ahead: Proposed Changes

In the Spring Quarter of 2002, HTOL will be offered again in largely the same manner as in 2001. In an effort to increase enrollment to approximately 15 students, HTOL will be marketed

to students who are not enrolled at the University of Washington. This process may be coordinated through the University of Washington Extension, a distance education organization.

All technology issues will be addressed, especially the problem with the progress/records feature in HTOL. In addition, the threaded discussion board will be changed so that comments and questions are anonymous. This change may increase student-student interaction and reduce the number of individual questions directed solely to the instructor.

Beyond 2002, HTOL may be modified to facilitate asynchronous delivery. This may be better for the students and will provide greater flexibility for students and for the Department. The Chemical Engineering Department plans to develop two more distance courses in order to facilitate the growth of a healthy co-op program. Mass Transfer and Reactor Design are the two key Chemical Engineering courses that inhibit students from accepting Summer-Autumn co-op assignments. Consequently, these are the two candidates for distance-learning courses in the immediate future.

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WILLIAM B. BARATUCI
William B. Baratuci is a Senior Lecturer in the Chemical Engineering Department at the University of Washington. He currently focuses his energies on computer-based and web-based instruction. Prior to joining the faculty at the University of Washington, he was an Associate Professor in the Chemical Engineering Department at Rose-Hulman Institute of Technology. Baratuci@u.washington.edu

ANGELA R. LINSE
Angela R. Linse is designing and delivering the instructional development program for the Center for Engineering Learning and Teaching (CELT). As CELT's instructional consultant, Linse provides services to engineering faculty at a variety of scales (individual, departmental, college, and national). She works with engineering faculty to design courses that enhance learning and teaching and incorporate information from current research on student learning.

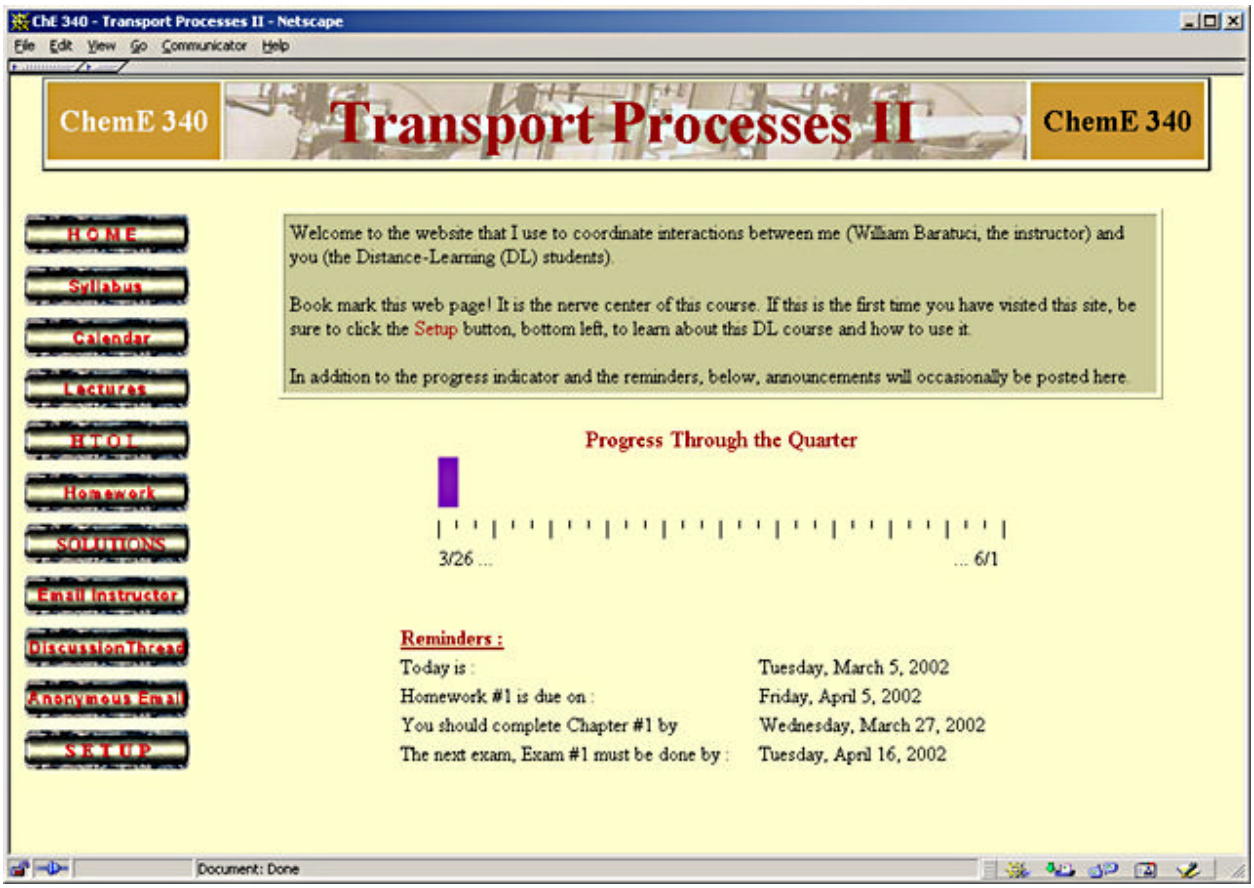

Figure 1. Screen capture of the homepage for the course website.

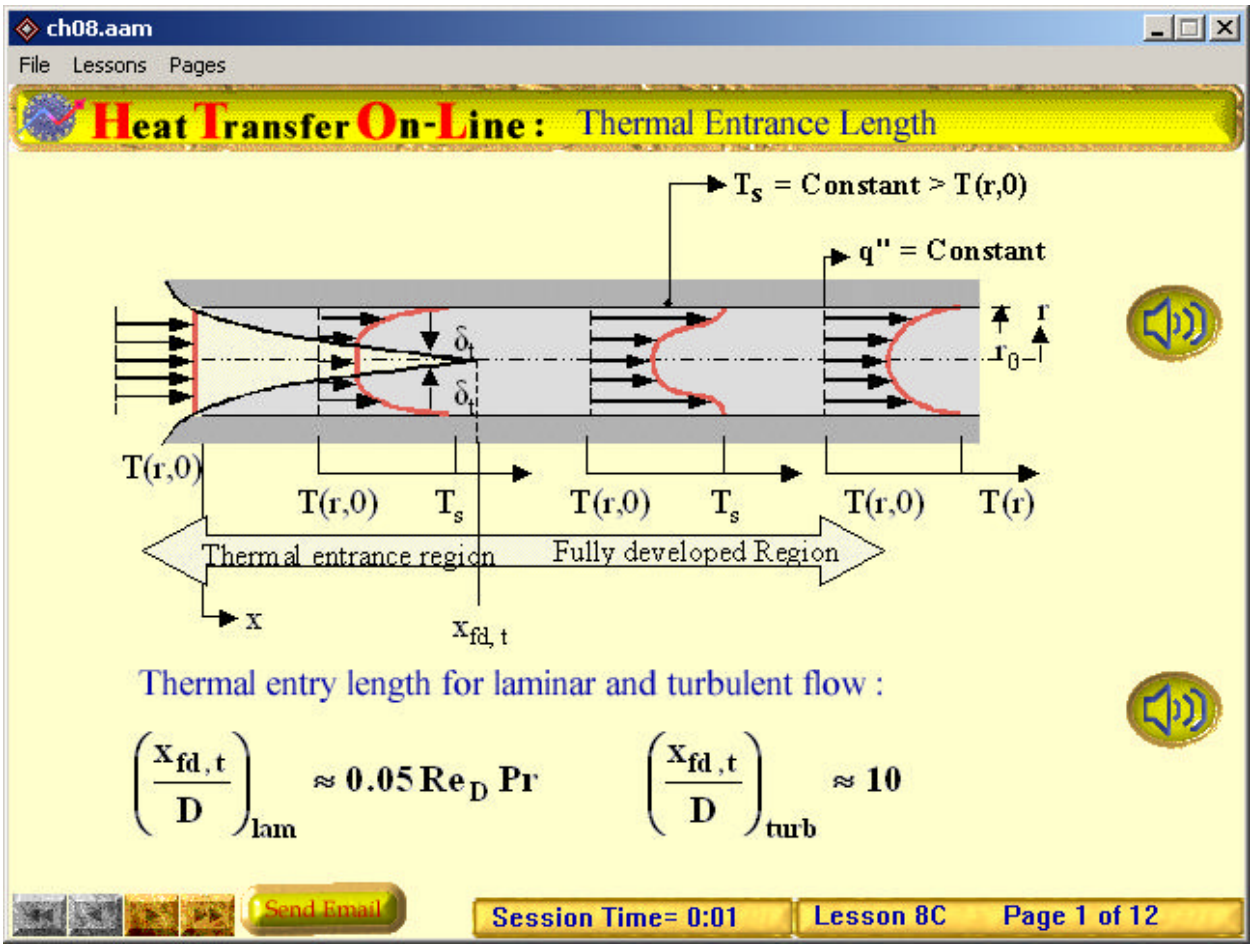

Figure 2. Screen capture of a typical screen from a lesson in HTOL.

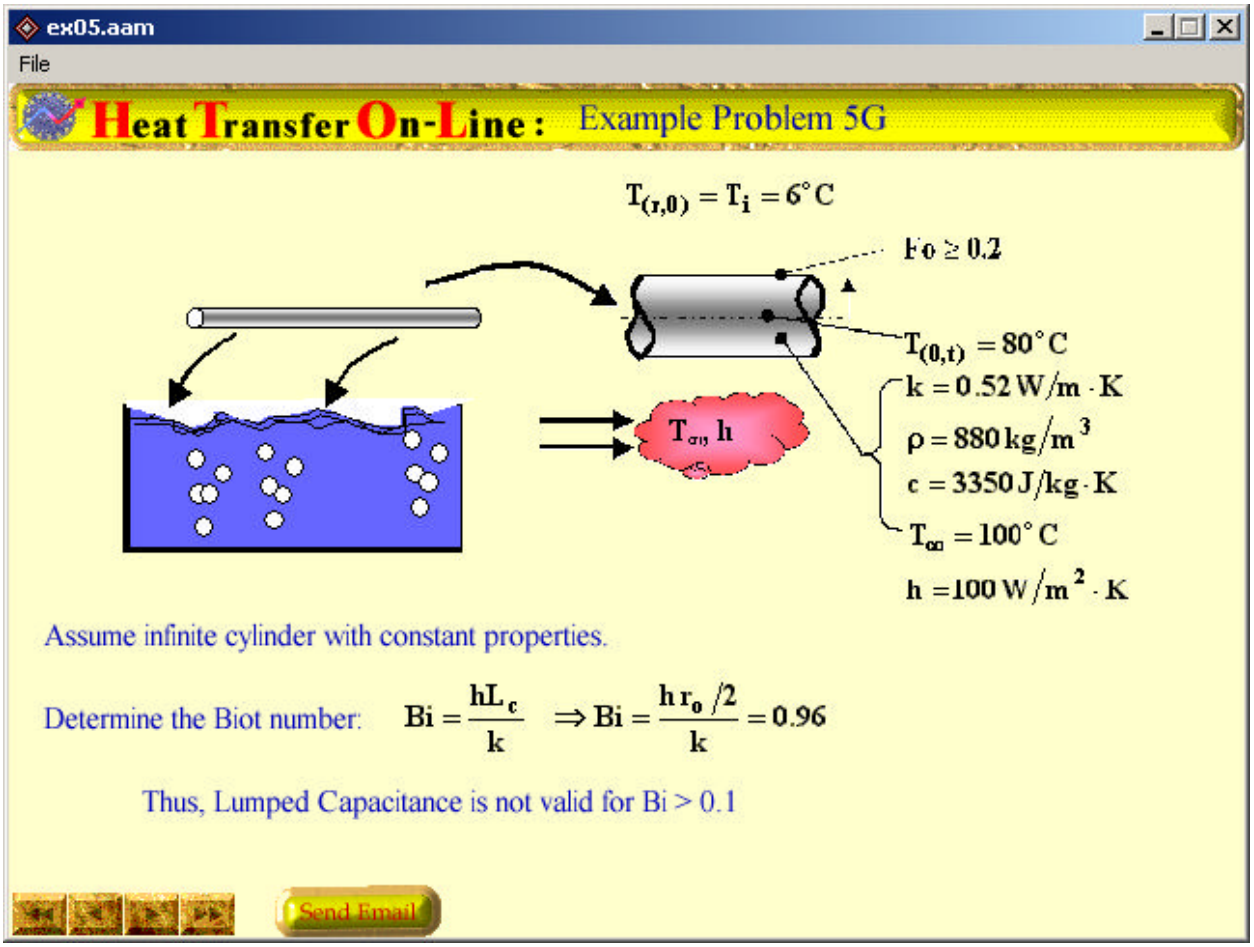

Figure 3. Screen capture of a typical screen from an example problem in HTOL.

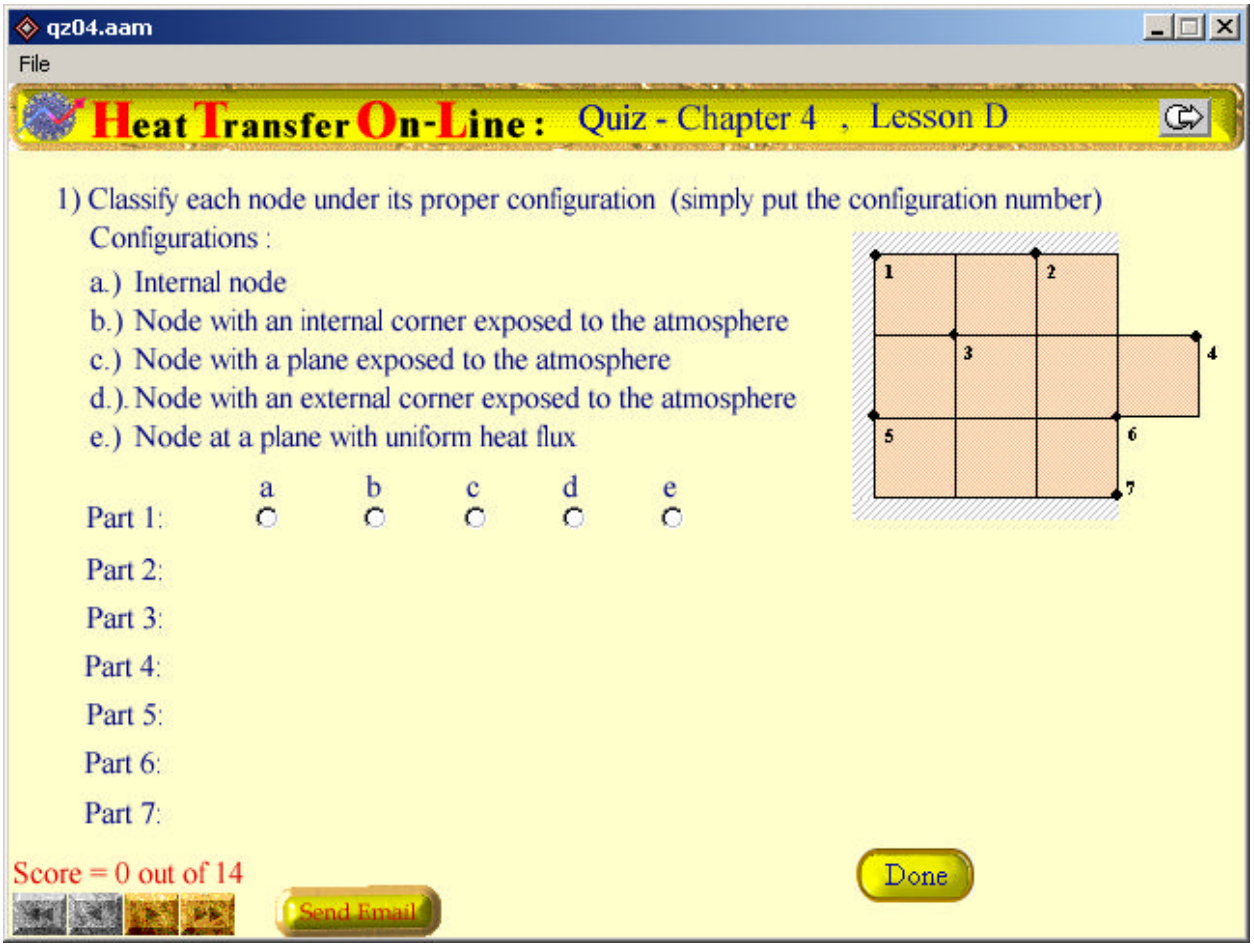

Figure 4. Screen capture of a typical screen from a multiple choice quiz question in HTOL.