Teaching Material and Energy Balances on the Internet

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Abstract

Strategies for designing effective multimedia educational materials for lessons that are delivered over the Internet will be illustrated using lessons developed for the sophomore-level chemical engineering course on material and energy balances. The advantages offered by the Internet may be exploited to create a valuable educational experience for the student that cannot be duplicated in the formal classroom. These advantages include: i) convenient access to the course from any location and on any schedule; ii) an added level of communication of the scientific concepts through well-designed audio-visual content (including voice, simulations, animations, pictures, and video); iii) the students' control of the pace of the course; and iv) the ability to easily integrate problem solving with the "lecture" component of each lesson. We have developed an Internet version of CHE 201: Material and Energy Balances that illustrates some of the potential for delivering college courses over the Internet. Features of this course include: i) hour-long lessons that are delivered using voice, text, pictures, simulations and animations; ii) sets of 10 to 20 short answer questions that the students encounter about every 20 minutes and are designed to reinforce the concepts that they just learned; iii) an electronic bulletin board (called the WebTalk discussion system) that everyone can access which includes student questions that are updated and answered daily; iv) weekly homework assignments (with posted solutions), and quizzes as well as regular exams that are administered by an approved proctor; v) a cooperative group project in which teams of students work together over the Internet; and vi) a hypertext glossary that can be accessed by clicking on the word to be defined or by moving to the glossary web page.

Introduction

Overview of the evolution of the Internet. If you are looking for the date that the Internet started, you would probably choose December of 1969 when computers at UCLA, Stanford

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Research Institute, University of California at Santa Barbara, and the University of Utah were connected under support from the Advanced Research Projects Agency.[1] In the following years, Universities were added to this network at an accelerating rate until nearly every University was connected by the mid-1980s using an Internet backbone that was maintained by the National Science Foundation. The Internet was originally designed to provide a communications network that would function even if some of the sites were destroyed by nuclear attack. Since the Internet was initially funded by the government, its use was limited to research, education, military and governmental purposes. Commercial uses were prohibited unless they directly served the goals of research and education. This policy continued until the early 1990's, when independent commercial networks began to grow. It soon became possible to route traffic across the country from one commercial site to another without passing through the government funded Internet backbone. In May of 1995 the National Science Foundation ended its sponsorship of the Internet backbone, and all traffic relied on commercial networks.

Today the Internet is growing at an enormous rate and is destined to impact nearly every aspect of modern society. There have been several attempts to characterize the growth and demographics of the people using the Internet. For example, in their annual Internet Domain Survey, Network Wizards[2] has estimated that there were a total of 376,000 Internet hosts on-line in January of 1991, 4,852,000 in January of 1995, and 36,739,000 in July of 1998. A series of studies conducted by Nielsen Media Research and CommerceNet[3] estimated that the number of Americans using the Internet grew from 52 million in September of 1997 to 70.2 million in August of 1998 (35% growth in an 11-month period). The highest growth in Internet usage was observed for women and minority groups. For example, the growth rate for black Americans was 53%, for American Indians was 70%, and for women was 50%. The total of 70.2 million people accessing the Internet represents 35% of the US population over the age of 16. The 1998 Nielsen–CommerceNet study also found that for the first time, over 50% of both males and females in the 16-24 year old age group regularly use the Internet. This accounts for 18.8 million Americans in the prime college-age years.

The demographics described above indicate that nearly every segment of American society is gaining access to the Internet. Therefore, the Internet is a powerful tool for reaching college students. Many college professors have recognized the utility of the Internet for enhancing the educational experience of students in their traditional "lecture" courses. In this capacity, the Internet is useful both as a means for the student and professor to gather information to use in the course and a convenient, easily-accessed venue to post course information, such as the syllabus, homework solutions, group assignments, *etc*. However, the Internet is destined to have its greatest impact on college education not simply by enhancing traditional, on-campus, courses, but by delivering complete courses to students who are unable to attend the classes on campus. The potential of the Internet for effective distance learning has been widely recognized, and the number of courses offered on-line grows each year. For example, at Michigan State University, the Internet offering of college courses has grown from five in the spring of 1997 to 30 in the spring of 1999, and other universities have undoubtedly seen similar growth in their on-line offerings.

Benefits of Internet delivery of college courses. The Internet offers several important advantages for the delivery of college course content. Foremost, the Internet offers convenient access to the course from any location and on any schedule. An Internet course can be delivered through any computer that has access to the Internet and can be offered any time, day or night. This essentially unlimited access to college courses could have a tremendous impact on the American society and economy. Not only can traditional college students more easily integrate their courses with jobs and extra curricular activities since they can receive the course content from their home or dorm room, but the Internet can provide access to nontraditional students who would otherwise be unable to take the course at all. This is especially true since Internet access is now available in nearly every office, library, and high school, as well as many households. Due to this convenient access, Internet courses could be used for continuous retraining of the industrial workforce in the rapidly changing economic landscape. An Internet "continuing education" course can be easily integrated into the normal work schedule, helping the students to realize how the material they are learning is relevant to their job. In addition, accelerated high school students could use the Internet to take college courses to enhance the high school curriculum, cooperative education students could take courses while they are on work assignments, *etc*.

A course delivered entirely on the Internet can be at least as effective as a traditional "lecture" course if it is properly designed. The features offered in a multimedia computing setting can be used to create a highly effective learning environment; however, not every course that has been offered on the Internet takes full advantage of these features. For example, if videotape of a traditional lecture is simply posted on the Internet, the learning experience for the Internet student will invariably be worse than that for a student in the classroom. The Internet student does not get the chance to ask real-time questions like the students in the classroom, and generally the audio and video quality of this type of Internet class are not optimal. Clearly the development and delivery of an Internet course presents different challenges than a course that is taught live in a classroom. The course should be developed in such a way that it accentuates the advantages and features offered by a multimedia computer venue, while minimizing the inevitable disadvantages.

We believe that a multimedia-computing environment offers many advantages that can not be duplicated in the traditional classroom. For example, since each student takes the course sitting directly in front of their computer monitor with a speaker on either side (or using headphones), the delivery of the lesson is in some sense optimized for all students. This is not always the case in a traditional course in which upwards of 100 students may be seated in a room, and many students have a sub-optimal view of the lecture. In addition, the multi-media delivery of the lesson material can be more thought-provoking and more engaging than a traditional lecture. A well-designed Internet course can provide an added level of communication of the scientific concepts through carefully planned audio-visual content (including voice, simulations, animations, pictures, and video) that can be continuously updated and improved. Finally, an Internet course allows each student to control the pace of the course to suit his or her unique style of learning. Again, this flexibility in pace is hard to duplicate in a traditional classroom where the instructor must be more concerned with the class as a whole than any individual student and therefore adjusts the pace to the "average" learning pace of the class. In a related

point, the web allows student problem-solving time to be easily integrated with the "lecture" component of each lesson. This can be especially important for engineering courses in which it is through the act of solving problems that the students do most of their learning.

Reasons for selecting Material and Energy Balances for an Internet course. We believe that the sophomore level chemical engineering core course on material and energy balances is a good choice for a course to be delivered on the Internet for several reasons. Although this course may be given different names, essentially every curriculum in the country offers this course and more than 80% of these courses use the textbook *Elementary Principles of Chemical Processes* by R.M. Felder and R.W. Rousseau.[4] One important reason that this course is well-suited to being taught on the Internet is that it is a problem-oriented course that can take advantage of the Internet model since the students can fully integrate the problem-solving experience with the rest of the lesson. More than any other course in the curriculum, the concepts in this course seem trivial to the students when they hear them in the lecture, but are much more challenging when they try to apply them to solve problems. In addition, the students can "replay" any part of the Internet lesson as many times as needed until they understand the concepts being taught. This feature is important for a problem-solving course in which a student must understand general concepts that can be applied in many different ways rather than memorizing facts or figures. Some students inevitably have to see a concept several times before it finally makes sense, while others pick up these new ideas very quickly.

Other reasons that the material and energy balance course is well-suited for the Internet derive themselves from the ability to reach a diverse set of students with widely different schedules. For example, *Material and Energy Balances* is the largest service course in the Chemical Engineering curriculum at Michigan State University, with students from chemistry and environmental engineering required to take it for selected options. The flexibility of the Internet can alleviate scheduling problems that occur when students from a variety of programs are required to take the same course. The Internet section also allows the offering to be expanded to every term (fall, spring and summer), which is important both for the service aspect of the course and for transfer students. *Material and Energy Balances* is often a problematic course for students who spend two years at a community college before transferring to a four-year institution for their final two years. This course is normally taken in the second year for on-campus students and serves as a prerequisite for many of their junior-level courses. The availability of the course on the Internet allows these students to take the course in the summer after their two years at the community college and thereby allows them to start their junior year essentially in sequence. Finally, an Internet version of *Material and Energy Balances* could serve a "continuing education" role for industrial chemists and technicians, or for chemistry undergraduates who wish to pursue a graduate degree in chemical engineering. The chemical process and problem-solving concepts covered in this course provide a valuable engineering perspective for these audiences.

Objectives of this paper. In this paper, we will provide our perspective on how to develop and deliver effective Internet courses by describing our experience with the Internet version of CHE 201: *Material and Energy Balances* that was offered for the first time in the spring semester of 1999. This course is the output of a multidisciplinary team, and we hope that the account of

how this team functioned will be useful for other faculty members who are considering developing courses to be delivered on the Internet. The primary objective throughout this project was to find ways that the Internet could be used to deliver an entire course which would ensure that the quality of the course would be at least as high as a traditional, on-campus lecture version of the course. Therefore, we worked to develop strategies to accentuate the interactive advantages offered by the Internet, while minimizing the educational disadvantages. The delivery of college courses over the Internet is truly in its infancy, and the potential for rapid growth in this area is tremendous. It is important for educators to engage in an active and critical discussion of the possible educational models at this early stage of development of Internet courses. We hope that the presentation of our thoughts on effective strategies for Internet courses will help to inspire further dialog and discussion about this burgeoning educational medium.

Strategies for Designing Effective Multimedia Educational Materials.

General philosophy of the Internet course. The recent proliferation of college courses offered on the Internet has shown that there are different philosophies regarding style and structure of these courses. The simplest approaches that have been used are to post lecture notes or slides, or to film traditional classroom lectures and make them available over the Internet. This approach essentially uses the Internet as an alternative venue for dissemination of information in the same format as a traditional textbook or lecture. While this approach allows Internet courses to be developed quickly and therefore has the advantage of expediency, it does not utilize the unique educational advantages offered by the Internet. We subscribed to a different philosophy in the development of the Internet version of CHE 201, *Material and Energy Balances.* We tried to use the features offered by multimedia computing to create an added level of communication beyond simply posting notes or slides. Therefore, our lessons are delivered using a combination of audio and video to explain the course concepts (these are described in much more detail below). In addition, we integrated many interactive and communication features into the lessons. For example, there are e-mail links to the instructor on every page, and there is a "Webtalk" discussion room that everyone can access and can post questions and comments to the rest of the class and to the instructor. Each student can customize their "profile" in this discussion room with text and graphics. In this "virtual classroom" we hope to foster peer-peer interactions similar to the discussions students have with one another after class outside the traditional lecture room. We hope that this use of the Internet as communication medium can help overcome the isolation and lost sense of community that can occur in some online courses.

Hardware and software requirements. The Internet course was developed with the strategy that the hardware and software requirements should be basic enough to reach the widest possible audience. Therefore, the course was developed in such a way that it would function well for a student using a PC computer with at least a 486-class processor or a Macintosh computer with System 7.1 or higher. The computer should be equipped with at least 16 megabytes of RAM and at least a 14.4 kbps modem (or a direct connection to the Internet through a network card). In addition, the software required to hear the audio, run the animations, and play the video clips is all downloadable free of charge over the Internet. Finally, the course will work with a variety

of Internet browsers, including Netscape version 3.0 or higher and Microsoft Internet Explorer version 3.0 or higher.

Course structure and style. The structure and style of lessons to be delivered on the Internet can have a significant impact on their educational effectiveness. In the Internet version of *Material and Energy Balances*, we decided to lead the students through the course at the same pace they would progress through the traditional lecture version of the course. The students proceed through the course by completing two Internet lessons per week. Each lesson is designed to take roughly an hour to complete and is delivered using voice, text, pictures, simulations and animations. About every 20 minutes, the student encounters a set of 10 to 20 short answer questions that are designed to reinforce the concepts that they just learned. The student reads each short question, then develops her brief answer (a few words, a number, *etc*) before clicking on the "Answer" button to access a pop-up screen with the solution. These questions are designed to maintain the focus on active learning. Printable transcripts of the audio narration are available for each lesson, and the Web pages are formatted for easy printing. In this way lessons are structured to support different learning styles as well as hearing impaired students. We anticipate that most students will find it most effective to use both the audio and the video components; however, students can obtain all of the educational material in the lesson without using the audio.

The course includes a cooperative learning group project called the "People Balance Project" in which the students work together in interdependent groups of five, with each group member assuming a different role essential to the success of the project. In this project each group collects data on the people entering and leaving a "system" of their choice (which may be a building, a portion of a building, a plot of land, *etc.*), then uses this data to perform both differential and integral people balances. The following aspects of the project require effective teamwork to be successfully completed: i) defining the role of each team member, ii) choosing a "system" for study, iii) formulating a postulate to be tested experimentally, iv) developing an experimental plan for data collection, v) coordinating the team's effort to collect the data, vi) analyzing the data to test the postulate, and vii) reporting the research results to the rest of the class on the Internet. This project is designed to enhance team skills and requires the students to find effective ways to communicate with one another from remote locations. A recent article in *ASEE Prism* highlighted the fact that practicing engineers are increasingly being required to work together on the Internet to complete projects and that project web sites are commonly being defined to coordinate this work.[5] Therefore, the electronic communication skills developed in this course may directly benefit the students in their careers.

There are several options regarding the policy for homework, quizzes, and exams in an Internet course, and the best option depends in part on the size of the course enrollment and the proximity of the students. For a problem-solving course such as *Material and Energy Balances*, homework is an essential part of the learning process; therefore, it is important to encourage the students to work these problems on a consistent basis. When the course was taught in the spring of 1999, the enrollment was small enough to allow the homework to be collected, graded, and returned each week. When the enrollment becomes too large, this may become logistically infeasible. In this case, we plan to assign the homework each week and to post the completed

solutions on the Internet to allow the students to check their solutions, but not to collect the homework. Rather we will have weekly quizzes based upon the homework that can be readily collected and graded via e-mail. For exams, we decided that all students will take the exam at the same time and that students able to drive to campus will take the exam in a classroom administered by the instructor. Remote students must establish an approved exam proctor, such as a nearby college professor, high school teacher, or librarian. We will then fax or e-mail the exam to the proctor, who will administer the exam in the prescribed manner.

Multimedia computing features used to maximize the interactivity of the Internet lessons. The capabilities and features offered by multimedia computing allow animations and videos to be easily integrated into the lessons. For example, animations may be used to illustrate complex concepts or experiments that are difficult to draw on the chalkboard or overhead transparencies of traditional classrooms. In many cases, the motion illustrated in an animation is useful to explain a concept and is difficult to embody in a still picture. Animations or video clips can be directly embedded within lessons at appropriate points much more easily than bringing video equipment into a traditional classroom. Digital videos and animations allow the student to control their viewing: they can play and replay the clips as many or few times as desired, pause to examine stills within the video, step through frame by frame, *etc*.

In the Internet version of *Material and Energy Balances*, we included an animation of an experiment that Joule reported in his landmark paper entitled "On the Mechanical Equivalent of Heat" in 1849.[6] In this experiment, Joule showed that potential energy possessed by a weight could be converted to internal energy in a tank of water. Joule measured the temperature rise in an insulated tank of water that was stirred by a paddle wheel driven by two falling weights. The animation includes a water-filled vessel with weights on either side. The weights are attached to ropes that pass over pulleys (to direct them horizontally), and wind around a spindle that is attached to a shaft extending into the tank from above. The shaft is attached to the paddle wheel, and when the weights descend, the paddle wheel turns, and the temperature of the water increases (the temperature increase is illustrated by the mercury level rising in a thermometer). The animation is used to illustrate the application of the energy balance to three different thermodynamic systems: i) the experiment as a whole, including the weights, paddle wheel, and water (potential energy is converted to internal energy), ii) the weights and paddle wheel, excluding the water (potential energy is converted to shaft work), and iii) the water alone (shaft work is converted into internal energy).

Other features incorporated in the course are used to make the lessons convenient to use and easy to navigate. A prominent example is the use of hypertext, menu-bars, and multiple navigational pathways that make it very easy to move from one section of the course to another. For example, any lesson can be accessed in two clicks or less from any other page in the course. Similarly, the following pages can be reached by clicking the appropriate entry on the menu-bar included on every page (therefore they are one click away): the "Help" page that lists the hardware and software requirements and the procedures for navigating the course; the "Lessons" page that lists the course topics; the "Objectives" page that lists the learning objectives of each lesson; the "Transcript" page that allows the students to print the transcript of the lesson narration; the "Glossary" page that allows the students to access the entire glossary for the

lesson; the “Calendar” page which lists the weekly assignments for lessons, reading, homework and exams (after they are due, the homework and exams solutions can be accessed here); the “Webtalk” discussion room (see above); the list of classmates; and the course credits. In addition, the hypertext glossary can be accessed by clicking on the word to be defined or by moving to the glossary web page. The glossary is implemented using a pop-up window that allows the student to view glossary definition and the context in which it appears on main page at the same time. Finally, each page includes a pop-up menu on the bottom of the page that allows the students to jump to any other page in the lesson.

Allocation of tasks for the development of an Internet course. The development of an Internet version of a college course is a major undertaking that will invariably require the interdependent efforts of several people for its successful completion. Facilities and support staff for such endeavors will obviously vary from one university to the next, but we feel that others considering developing such a course may benefit from a description of our experience in this area. We found that the tasks that must be completed to develop the course could be divided into the following classifications: i) development of the course content; ii) implementation of the course content on the Internet; and iii) testing, editing, and debugging of the lessons. Since each of these roles is substantial and takes a considerable time commitment, we found that it was useful to have a different team member take the primary responsibility for each of these aspects of the course development. The key team members were involved in all three tasks, thereby providing continuity of the course development and ensuring efficient management of the project.

The team member in charge of the development of the course content clearly must be a faculty member who is knowledgeable about the course and preferably has taught the traditional lecture version of the course a number of times. Each lesson began with this faculty member writing the scripts for the lesson. These scripts were generally more informal than a text book since they were eventually going to be delivered by voice and were more thorough and complete than a typical lecture, since the students were not going to have the chance to ask questions for immediate answers. Based upon these scripts, the text, pictures, narration, and animations for the lessons were drafted. In this step, the faculty member worked with team members involved in the implementation phase of the course.

For our project, the team member in charge of implementation was a member of the Virtual University (VU) at Michigan State University. The Virtual University's mission is to work with faculty to design and produce courses delivered via the Internet, and they assigned a Web producer for this project. This team member worked with the faculty member in charge of course content to determine how the VU’s artists and production workers could aid in the development of the course. The course content was provided to VU in the form of Word files (for text) and Wav files (for audio), and they transferred it onto the Web. In addition, the VU provided artists who developed the graphics and animations based upon descriptions provided by the faculty member in charge of course content.

We found that it was imperative to have a third team member in charge of testing, editing, and debugging. For testing of the completed lessons, it was useful to have students from the

traditional lecture version of the course "test-drive" the Internet version and make their suggestions for improvements. For example, based upon students' suggestions, the pop-up menu was added to bottom of the page, and many short audio files were combined to create longer sound files with fewer interruptions for moving on to the next page. Due to the complexity of the multimedia educational materials in which voice is combined with text, pictures, video, and animations, it was inevitable that each lesson contained errors that required multiple episodes of editing and debugging.

Software used for implementation of the course on the Internet. The web version of *Material and Energy Balances* was implemented on the Internet primarily using commercially available software packages. The onscreen text was developed using table construction features in Hypertext Markup Language (HTML). The templates were designed using HTML editing software packages such as MacroMedia's Dreamweaver and Claris' Homepage. The artwork for menu items, title bars and navigation elements were developed using Adobe PhotoShop. Video clips were captured with Adobe Premier, processed to achieve best compression settings with Terran Interactive's Media Cleaner Pro, and delivered over the Web using Apple's QuickTime format. Animations were developed using MacroMedia Director and MacroMedia Flash and were converted to QuickTime movie files for delivery via the Web. QuickTime was selected for delivering the animations rather than Sockwave (which is MacroMedia's technology for directly delivering Director and Flash animations) because it was already being used for the video clips. In this way, the students did not have to download, install, and configure yet another browser plug-in to view course content. The narrations were recorded in Wav files using the sound recording feature in the Microsoft Windows operating system, and the audio files were edited, combined, *etc*., using the MacroMedia SoundEdit and Sound Forge XP software packages. The edited sound files were compressed using Real Player, and the streaming audio files are delivered over the Internet through Real Server. The clickable drop-down menus that can be used to navigate the lessons are implemented using a JavaScript function. Finally, the glossary pop-up windows were created with a simple JavaScript function to open a new window where an anchor to the glossary term and the related file are specified.

Interactive Preview of the Internet Version of Material and Energy Balances

An interactive multimedia preview of this Internet version of Material and Energy Balances (CHE 201) can be found at the Virtual University web site at Michigan State University (www.vu.msu.edu).

Acknowledgements.

The authors are grateful to the following people who contributed to the completion of this project: Monica Beard for HTML authoring and audio processing, Barbara Beckmeyer and Deon Foster for artwork, Andrew Kurtz for JavaScript template coding, and Kristy Ainslie for her appearance in the "Methanol Cannon" video. In addition, the following undergraduate students helped with the "test driving" or other development of the Internet course: Kristen Huntoon, Kira Glover, Carl Johnson Jr., Levi Banker, Rob Svoboda, Brian Ngo, Marcus

Worsley, Beverly Hinds, Kyle Paulson, Amanda Zadorski, Andy Wijaya, and Aaron Learman. Additional guest narrators included Kiran Baikerikar and Robert Cook.

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