Development and Implementation of a Computer-Based Learning System in Chemical Engineering

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Abstract

This paper describes the development and implementation of a computer-based learning system for the University of Missouri – Rolla (UMR) chemical engineering curriculum. The project has three major goals: provide a learner-centered study environment for our students, integrate the learning system into the department assessment plan and redesign a traditional classroom for synchronous delivery of the learning system. Systems like WebCT and BlackBoard are gaining popularity for course authoring and web-based delivery of course content; however, no single system meets all project goals. The current paper discusses our rationale in selecting the base software and provides a detailed description of the system hardware, software and the new classroom. The most time consuming effort involves the design and development of the resource modules; particularly those that involve mathematical equations, graphics or a high degree of interactivity. This paper discusses the steps involved in this process and provides examples of what can be done with current technology. Some sample content pages and assessment results from the undergraduate thermodynamics course are provided.

Project Goals and Objectives

The first project goal is to develop a learner-centered study environment. The current practice in our department is to supplement traditional chalk and talk lectures with information in Microsoft Word, Microsoft PowerPoint or HTML file formats. The information is static and available to the students asynchronous to the course. Some professors make all information available at the start of the semester while others make it available on an as-needed basis. There are advantages to both methods and the system should support both. Our experience with this technique is that students will print the information for their files; however, they treat it the same way they treat the textbook. Some students feel intimidated by the length of a module and dismiss it because they do not have sufficient time. Other students may begin the module but the material does not engage a number of senses for them to maintain interest. Finally, the assessment of learning progress and subsequent feedback to both the student and the professor comes too late in the learning cycle. With quizzes and homework, the feedback is days and with major tests it is months after students begin a module. Cognizant of these observations, we developed the following objectives:

- Develop a library of self-contained modules, termed Learning Resource Modules (LRM),

each with a specific educational objective. Each LRM focuses on a single concept or skill that the student must master. The LRM is small, interactive, and uses animation and sound to engage the student.

- Develop a library of assessment tools for each LRM group. Automatic grading provides immediate feedback to the student. Feedback is given for both incorrect and correct responses. Individual assessment results are linked to each LRM.
- Provide a delivery mechanism that allows either random access or conditional sequential access to a defined set of the LRM library. The professor controls when and how the LRM sets are made available to the student.

The second project goal is to integrate the learning system into the department assessment plan. The currently accepted, two-loop pictorial best represents how Criteria 2000 functions within a department. The second loop assesses student learning in relation to defined outcomes. Departments then use these assessment results to determine how well they are meeting stated program goals and objectives in the primary loop. By linking the objectives of each LRM and its associated assessment(s) to an outcome, a major portion of the assessment process becomes automated. The system should satisfy the following objectives:

- Develop the set of educational objectives for each LRM and associate these with program outcomes. The system should assist in defining these associations and should maintain all necessary relations between outcomes and assessment results.
- Monitor and report student performance on both individual and group bases. The professor may define a group to be some set of a class; however, the department may need the performance results of all students for a particular program outcome.
- The performance results and associated relations among LRM objectives and program outcomes should persist in a database. This provides necessary documentation for ABET review.
- Perform gap analyses for individual students. Each student should have a report listing what outcomes she has mastered and which ones remain. The gap analysis assists in providing a personal development plan for each student.

The final project goal is to redesign a traditional classroom for synchronous delivery of the learning system. The most common classroom at UMR consists of a screen, chalkboard, and desks or tables for the students. Audio/video carts are available on a reservation basis. Most carts contain an overhead projector with one video projector in the department. Specific lectures that require students to use some type of computer workstation are scheduled and held in a separate computer laboratory. The overhead projector is easiest to bring and setup for a class. The video projector and laptop require space and time to setup. Most often the single screen in the room does not provide optimum viewing to students in the back or along the sides of the classroom. Professors who use a computer lab for specific lectures commonly complain about students accessing the Internet or communicating e-mail during the lecture. From the project inception, the authors knew that a significant portion of the system would be used for synchronous delivery in

the classroom. Lecture materials easily derive from segments of the LRM library. A pre-lecture assessment could provide immediate feedback to the professor that influences what topics she would stress in that specific lecture. Some assessments must be performed in a secure, supervised manner. The classroom must have the necessary equipment to deliver the multimedia content of the LRM. In addition, many classes require students to learn and use software as a routine part of the course content. The classroom design must meet the following objectives:

- Provide sufficient student seats and an instructor console that optimizes the view of a central screen. The project is limited to a room that the department "controls" and there must be sufficient seats to minimize the number of sections required in a given course.
- Provide state-of-the-art technology for delivery and instruction of multimedia content.
- Provide each student with a computer workstation.
- Provide absolute control of the student workstation from the instructor console

Developing Learning Resource Modules

The first tasks identify course objectives and source materials. A course syllabus provides a good starting outline, but greater depth and detail reduces development time. It is imperative that one abstracts each level of the outline to a specific educational objective. For example, in the undergraduate thermodynamics course, students work several classes of problems: closed systems, open systems, combined steady state and open systems, etc. The course outline may devote blocks of time and material to each type of problem; however, the specific educational objective is to teach students to simplify the general mass, energy and entropy balances for any set of problem specifications. To achieve this objective, students must understand heat, work, thermal properties associated with flow streams, etc. Each of these develops into a separate LRM with its own objective. By repeated application of this process, one defines the basic set of LRMs for a course. One of the most crucial elements in the development of the LRM is the storyboard for the presentation. The storyboard details all entities used in the LRM, lists every event that occurs and choreographs the entire presentation. In developing the storyboard, the developers must continually ask if the presentation design meets the educational objective. Will the students learn the proper material when interacting with the presentation? An integral part of the LRM is the assessment tool used to answer that specific question.

One must now develop all entities listed in the storyboard. In our case, most existing materials were in Microsoft Word, Microsoft PowerPoint or HTML file formats. Word has the capability to save content directly in HTML format. It does not directly support dynamic HTML, which is essential for motion within a Web page. Some form of a Web page editor is required. FrontPage 2000 offers easy conversion from Word documents and easily incorporates ActiveX controls within a Web page. Macromedia offers a suite of tools for Web development. DreamWeaver has features and capabilities similar to those in FrontPage. FireWorks provides good drawing tools and excellent graphics editing capabilities. FireWorks is noted for its support of vector-based graphics. Vector graphics scale nicely on a Web page and minimize file size compared to bitmaps.

Flash provides movement and animation to objects on a Web page. Macromedia includes a scripting language for Flash that allows some degree of interaction between the user and a web object. Although Flash can integrate sound, Director and the associated Lingo scripting language is best at choreographing an entire presentation. Macromedia also provides the AuthorWare tool, which provides a subset of the features in Director but is aimed at developing educational content. Macromedia provides some assessment tools in either AuthorWare or in a separate library to DreamWeaver. Adobe provides an excellent image editor in PhotoShop and a Web development tool in GoLive. For this project, the authors chose the Macromedia software suite since they offered several tools directed at educational content and assessment and since a nucleus of technicians on campus have some familiarity with the products.

Figure 1 shows the first screen of a sample Web page. This page is part of the exerciser developed to show students how to simply the general balance equations. A DreamWeaver template with cascading style sheets (CSS) defines the structure of this page. Any repeat uses of the page simply add small changes to the template. The problem statement was cut and pasted from an existing Word document directly into DreamWeaver. Formatting changed as specified by the CSS. FireWorks created the banner graphics defining each step in the problem as well as the radio buttons used to select the appropriate accounting period. Flash created the animation or motion in the picture of the compressor. The user may select to see the animation of the picture or not. The general balance equations are incorporated into the page using WebEQ. The equations are in MathML format. WebEQ allows the display of a description of each element when the mouse rolls over it. FireWorks converted all bitmap and JPEG files to vector format and stored the results in the Portable Network Graphics (PNG) file format. Figure 2 shows the second screen of the sample Web page. Immediately below the equation set is a set of radio buttons that the student may select. Each button causes the cancellation of particular terms from the general balance equations. Figure 3 shows what happens when the student states that there are no nuclear or atomic transformations during the accounting process. When this radio button is selected an X appears over the generation of mass and the generation of energy terms in the equations. This is accomplished by associating some JavaScript to the radio buttons when they are defined in DreamWeaver. Figure 4 shows that some selections are mutually exclusive. The three buttons near the bottom of the second column all pertain to the heat flow term. When the student selects any one of these three, the remaining two buttons become gray and disallow further selection. In any case, the heat term is cancelled from the balance equation. The same is true when the student selects the steady-state button at the top of the third column. All remaining entries become mutually exclusive. This same template may be used as an assessment tool. Once the student feels comfortable with her selections, she may hit the *submit* button at the bottom of the page for immediate grading as shown in Figure 5.

Selection of Base Software System

WebCT and BlackBoard are gaining popularity among University administrations as course

management software systems. WebCT has been at UMR for two years and BlackBoard is currently being installed. Either product allows a professor to display course content in a controlled fashion and has an assessment engine. The assessments consist of some form of multiple-choice questioning. The results are stored in a back-end database, which is typically either Oracle or SQL Server. The products report assessment results and usage statistics in a variety of formats. Both products authenticate users to the system, which requires someone to create and maintain userids and passwords. BlackBoard interfaces with several enterprise software products including PeopleSoft, which may automate userid and password maintenance. BlackBoard appears to have a rich set of collaborative tools, including a whiteboard for groups. A third product that is not yet popular among academic settings but has exposure to the corporate training environment is LIBRIX Learning from St. Louis, MO. LIBRIX has many of the same features of WebCT and BlackBoard in that it offers delivery of course content coupled with an assessment engine. However, the corporate audience that LIBRIX serves emphasizes the personal development and motivation of its employees more than the delivery of course content. LIBRIX is more of a performance management tool than a course management software product. The performance management features of LIBRIX are by far closest to meeting the assessment goals of this project than either WebCT or BlackBoard in their current forms. LIBRIX allows the definition of objectives for each LRM and tracks the completion of the LRM by each student. The objectives may be grouped as desired, which allows these to be linked to program outcomes. This data then allows the system to generate a gap analysis for each student or at the department level to generate a gap analysis by program outcome. In essence, it measures and manages the performance level of the students and of the curriculum. LIBRIX does not have as rich of a set of collaborative tools as BlackBoard.

The authors selected LIBRIX for this project. The local and company support for WebCT was minimal and had not gained a wide support group on campus. LIBRIX learning is located in St. Louis, MO, which is very close to UMR and the company representatives expressed an interest in working with the project. The campus is only recently starting a dialogue with the BlackBoard representatives who also express an interest in working on the projects. In our opinion, all three products suffer miserably in the area of assessment tools. None of these products support forms of assessment beyond multiple choice testing techniques. The integration of the general balance exerciser discussed above requires a custom and non-trivial integration to the back-end database. This is an area that needs considerable development for engineering courses.

Design of the Multimedia Classroom

The conversion included renovation of the classroom (a flat-floored, box-shaped room with dimensions of 30 feet by 30 feet by 10 feet) and installation of multimedia hardware and software to support instruction. The renovation involved construction of tiers for four rows of student desks (the front of the room was rotated 90° to improve the aspect ratio) and a small closet to house electrical and computer components. There are 36 student desks (one with handicapped access) each fitted with a computer, monitor (inset under a flat, glass panel in the top of the desk), keyboard and mouse. Carpeting, sound-absorbing wall panels, and indirect lighting (to reduce

glare on the flat glass panels in the desktops) were installed. The air conditioning system had sufficient capacity to accommodate the addition of the computers, however, additional electrical power was required.

Hardware

In addition to the 36 student computers, there is an instructor station with computer, monitor, keyboard, and remote mouse, a remote microphone-speaker system, an audio receiver, a document camera, a video cassette recorder (VCR), and a 42-inch plasma display fitted with a Matisse overlay. There is a ceiling-mounted video projector that projects images from the computer, VCR, or document camera onto a 100-inch screen. There is also a large white board. A high-speed data network (100 Mb/sec initially, but expandable to 1 Gb/sec) links the computers in the room to a dedicated server. The dedicated server and high-speed data network provides the necessary performance for graphics/compute-intensive applications (such as HYSIS).

Software

A suite of software that includes Microsoft Office (WORD, EXCEL, PowerPoint, and Outlook) and MathCAD is available to all UMR students. Chemical engineering students have access to additional software that includes MATLAB, PolyMath, HYSIS, Visio, and Icarus. Special software for the multimedia classroom includes classware and courseware.

Classware

Classware works in the classroom to allow the instructor to control/view each of the student monitors and to create, annotate, and/or save images. The SynchronEyes Teacher software places each of the student computers at the control of the instructor. The three principle functions of SynchronEyes Teacher are “lock”, “class”, and “show”. The “lock” function locks out each keyboard and monitor on the student computers. The “class” function displays an icon for each of the student computers on the instructor’s monitor. Double clicking on the icon displays the screen of the student computer on the instructor’s monitor with two pointers (one for the instructor’s mouse and one for the student’s mouse). The instructor can view the student’s work from the front of the classroom, can take control of the individual student’s computer to edit/annotate, and can display the student’s work to the rest of the class. The “show” function copies the instructor’s display to each of the student’s monitors. The SMART Notebook software works with the Matisse overlay to enable the plasma display to function as a touch-sensitive monitor for the instructor’s computer and allows images to be created (hand drawn or imported from other software), annotated (in various colors), and saved (to various formats including HTML). Any software on the instructor’s computer can be executed using the touch-sensitive display (in “mouse” mode) and simultaneously displayed through the video projector and/or copied to each student’s monitor. By switching the touch-sensitive display to “draw” mode, annotations can be added as an overlay. Figure 6 is a screen capture of the plasma display with Matisse overlay in which a graphical object, created in Visio and saved as a JPEG document, was opened with Smart Notebook and

annotations were added. The figure can be displayed to the entire class through the video projector and/or, by touching the "Show" button in the "My Desktop" window, on each of the student computers. Additionally, the annotated file can be saved as an HTML file and published to the web or can be copied and pasted to other software such as Microsoft WORD.

Courseware

Courseware enables the delivery of educational materials outside the classroom and automates assessment of student performance. The LIBRIX courseware enables the creation of web-based instructional modules that can be accessed asynchronously (at the student's convenience) and from virtually anywhere (in the classroom, from dormitories and computer learning centers on campus, or from off-campus sites). The LIBRIX software has instructional modules (called "courses" by the software), tests, and surveys. The instructional modules are web pages constructed by the course developer and embedded in the LIBRIX software. Tests composed of multiple choice or true/false questions are machine graded and the results stored in the LIBRIX database. Short answer or essay questions must be hand graded but the results are stored in the database. The period of time during which a test is available to the students, the passing score, the number of times a student can take an exam, and the makeup of the exam (for example, questions can be randomly drawn from a pool of questions) can be controlled from the software. Responses to survey questions are also stored in the database. Various reports can be generated from the data in the database to assess student performance.

The operation of the multimedia hardware and software is not imposing. An instructor can be trained to effectively use the classroom in less than 30 minutes.

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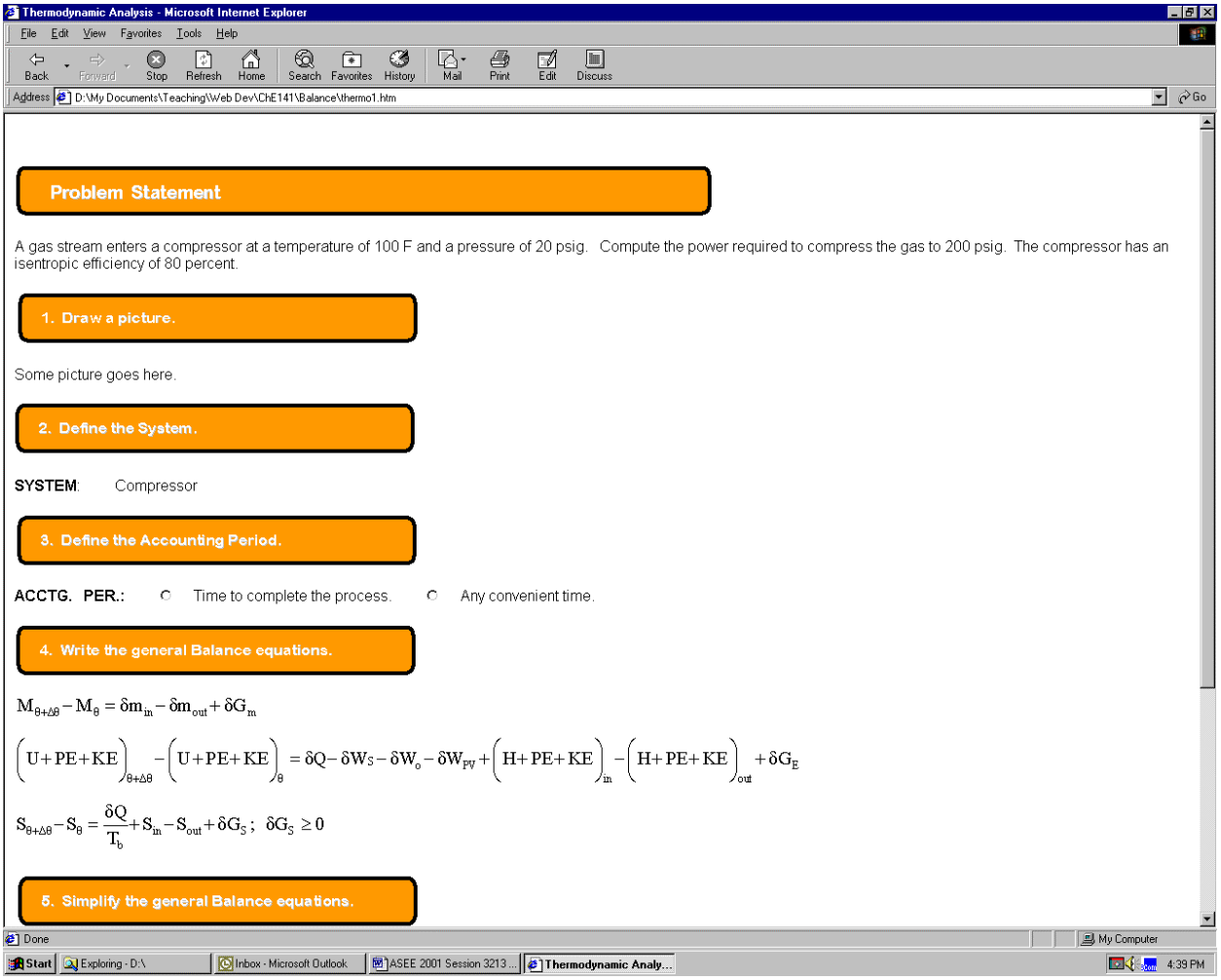

Figure 1. Problem Statement for the General Balance Exerciser.

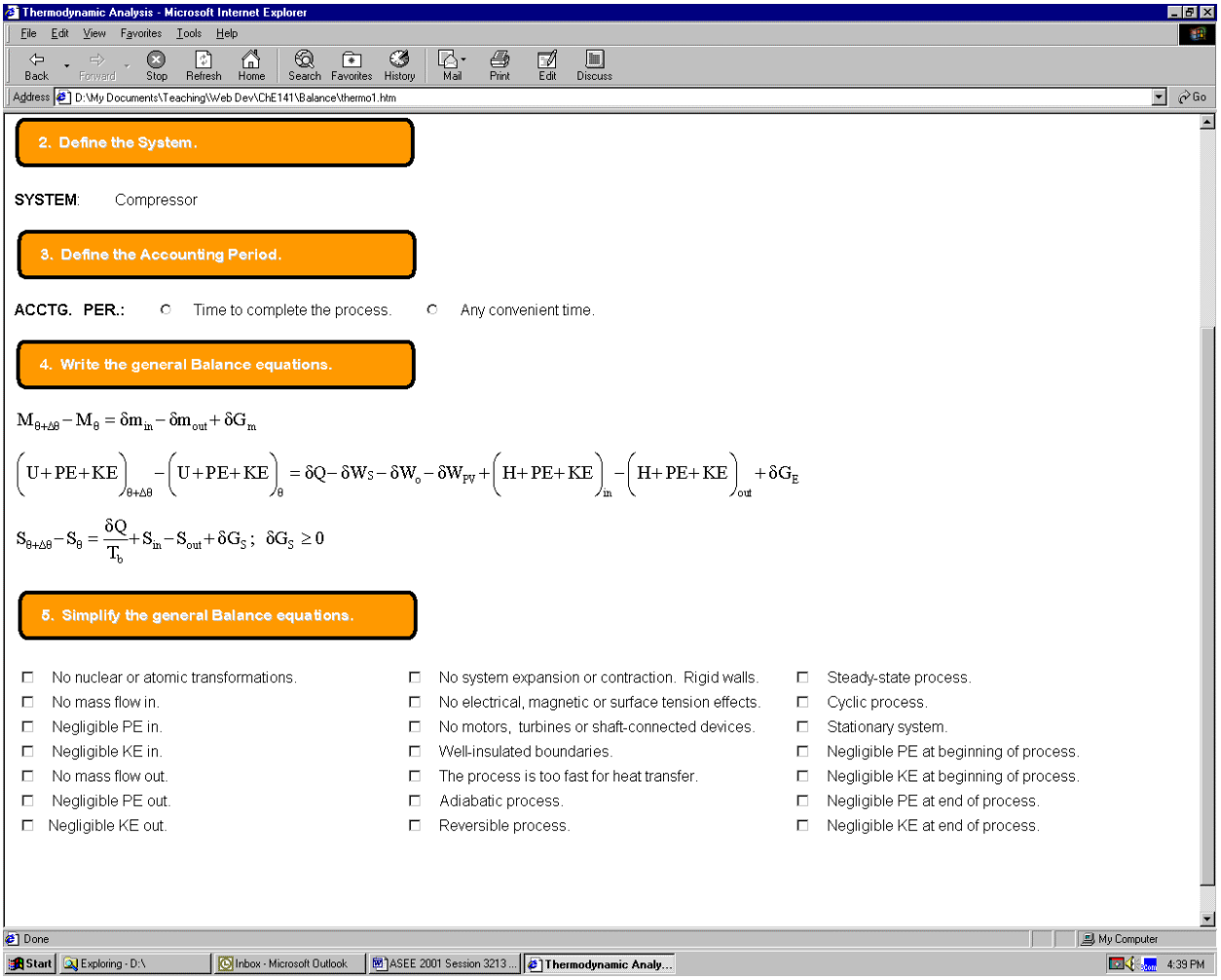

Figure 2. General Balance Equations and User Selections.

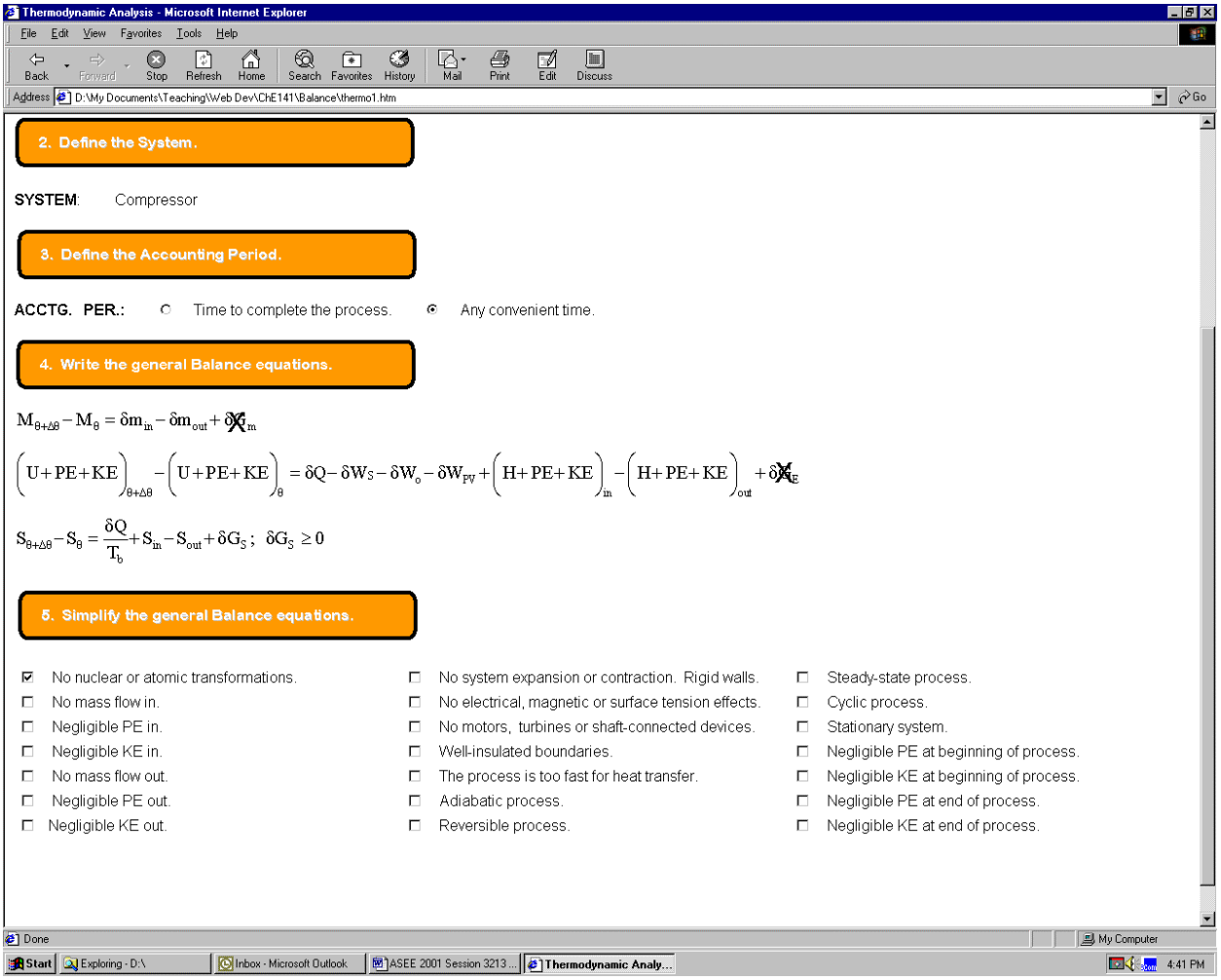

Figure 3. Sample Showing Cancellation of Generation Terms from the General balance Equations on Selection of the First Radio Button.

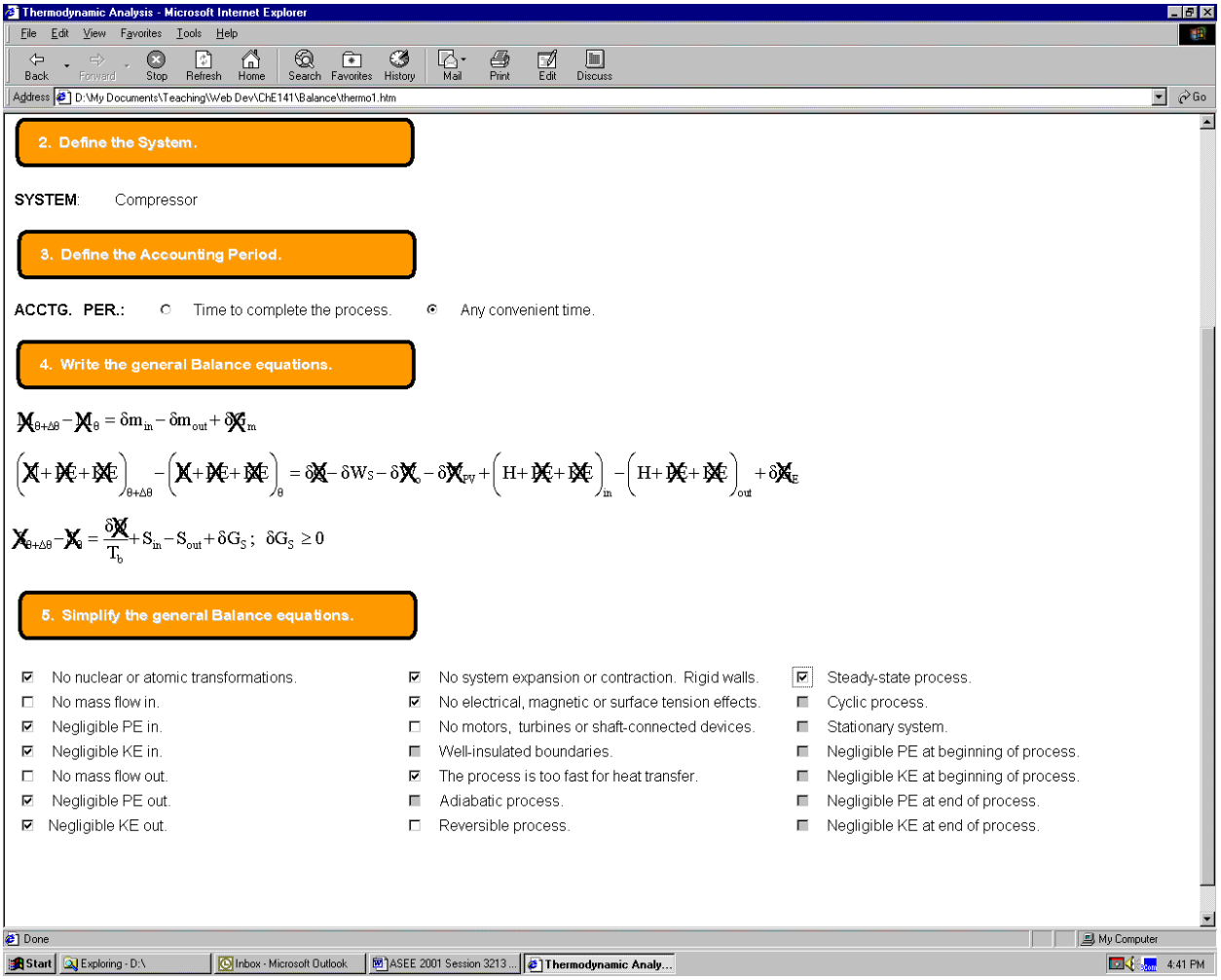

Figure 4. Sample Showing Mutually Exclusive Selections from the General Balance Equations.

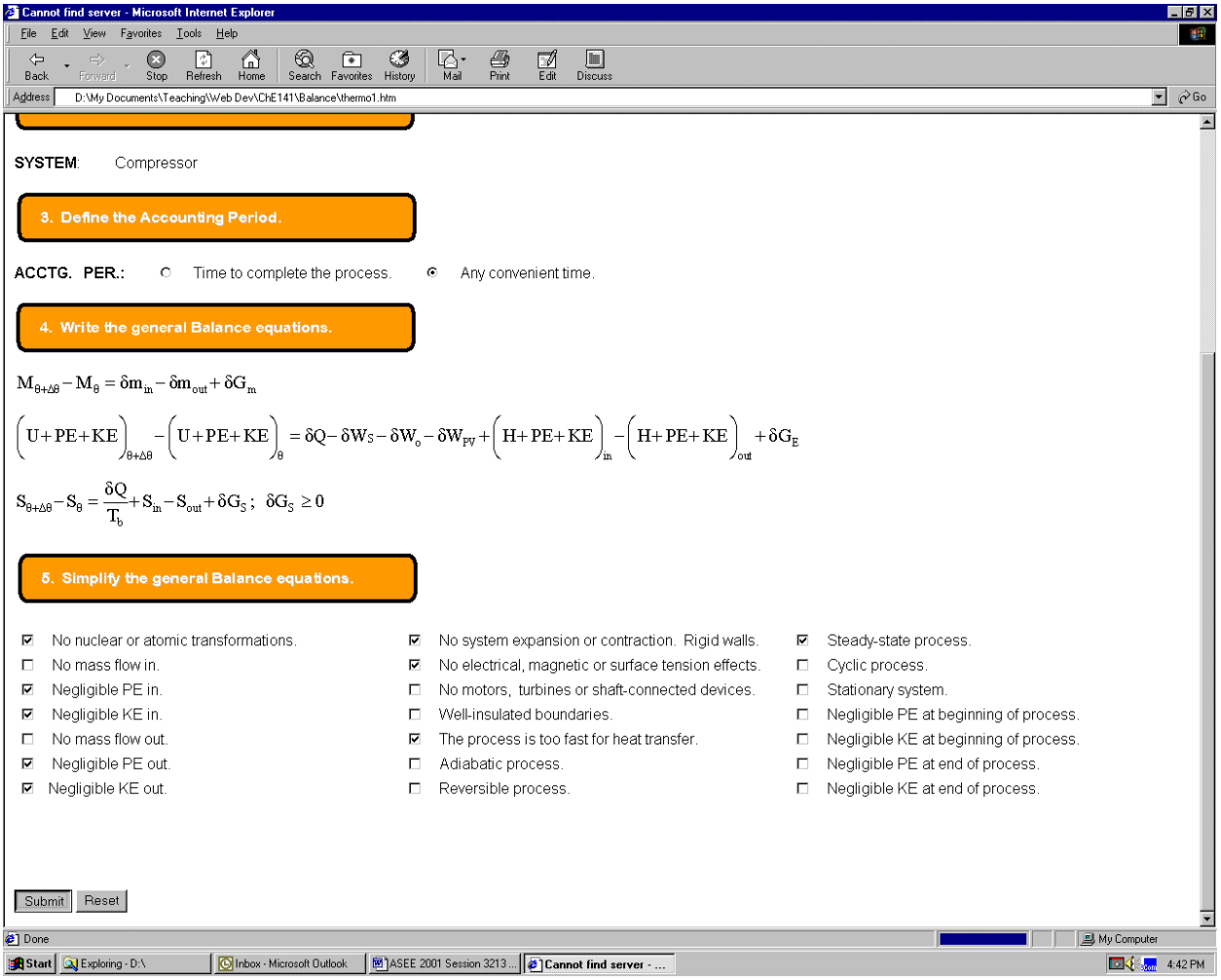

Figure 5. Example of Form Submission.

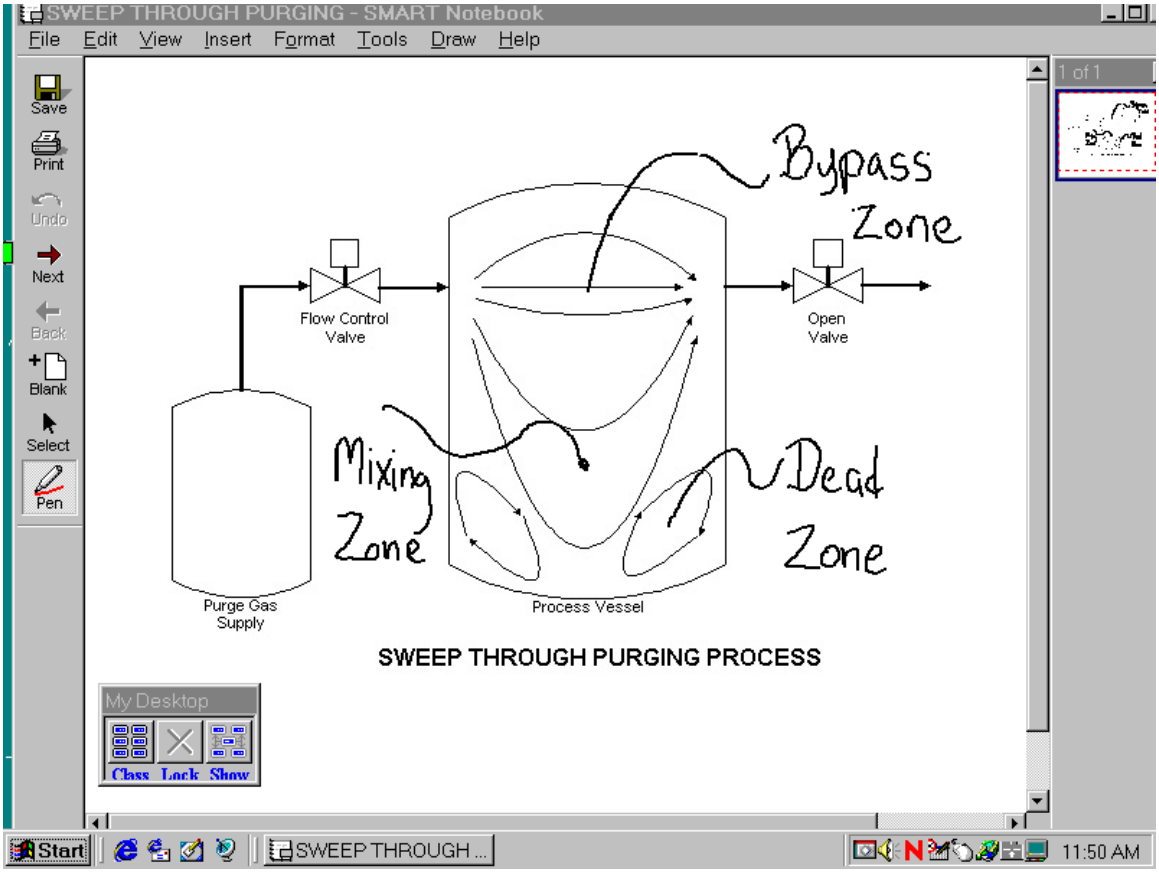

Figure 6. Screen Capture of the Plasma Display with Matisse.