Use of Interactive Web-Based Examples in Engineering Courses

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Abstract

The use of Web-based course materials is very attractive in engineering courses for many reasons. One benefit is that students can access material on their own time to fit their learning into their daily schedules. This can also make distance learning more effective. Another benefit is that materials can be used over and over again after their initial creation.

Like most technological advances, though, there are several negatives associated with on-line learning tools. From an instructor's point of view, Web-based educational materials take a long time to develop and implement. Secondly, very few engineering professors are proficient at using computer software to generate robust educational materials. To avoid having to become capable users of the new computer technologies, many of us often resort to using technologies that are easier to use, but may be less useful for students. An example of this is the use of "talking head" boxes on Websites where students can watch lecture materials that were previously presented in class. While it may be useful for students to be able to review lecture materials in this manner, students then miss the benefits of interaction with the instructor. Also, very little student processing of information may occur as they watch the materials.

To remedy some of these Web-based learning problems, Web-based computer materials were developed for an introductory chemical engineering course at the sophomore level. The examples attempt to improve problem solving skills by leading students through a series of questions demonstrating how complex solutions are created by integrating individual small steps. In early examples, students are asked very basic questions about the material. Students then fill in blanks on the Webpage, select from multiple answers, or seek more in depth help on the material. When students do answer a question, they are given instant feedback using Javascript enabled programs. Wrong answers lead to feedback on how the correct solution can be reached while correct answers allow students to move on to the next series of questions. The later examples are more difficult and ask students to do more steps simultaneously in order to fill in more than one blank or make more than one choice. This organization forces students to actively process the information in the example instead of just skipping ahead regardless of their comprehension.

These materials were used as a training tool in the introductory class for students who performed poorly on a midterm exam. Students were required to work through the examples and then to generate a list of questions about the material to identify where their difficulties lie. These students then went on to the next exam with much stronger skills in the critical topics

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covered by the Webpages. In general, their exam scores improved by about 20 points over the previous exam.

I. Introduction

The advent of the internet and all of the technologies that are supported through its capabilities has made new teaching tools possible. At the college level, computer based teaching methods have been implemented in various disciplines with some success[1]. These Web-based computer technologies include streaming video, posting class information, and using online chat rooms for specific courses. All of these methods can be used to replace traditional face-to-face instructional techniques when those methods are not viable[1-4], and to enhance traditional ones when they are available[5-8].

The use of Web-based techniques for teaching are attractive for several major reasons. First, distance education is much more attractive with the use of the Web[6]. Prior distance learning techniques relied on land-based mail systems and in having methods of administering tests at long distances, often involving a paid proctor who had to be physically with the student at the time of the test[6]. As technology has improved, it has become possible to update Web-based materials quickly and to use more effective Web-based testing methods to eliminate some problems with correspondence courses.

Another advantage to Web-based materials over traditional materials is that they can be used repeatedly by students throughout the semester as they review the course. The students can also move through the material at their own pace, unlike a traditional lecture which is paced by the instructor. The materials can be used by the instructor for several course rotations if the material does not need to be updated with new advances. This means that an instructor only has to create one set of materials that can then be used by students several times. A traditional lecture must be prepared each time that it is given, indicating that Web-based presentations of material may be more efficient for faculty.

II. The Web as Savior?

Claims about using emerging technologies in education have been made in the past, like the ones made about television in the 1930s and 1940s. However, we know that the use of television as a useful instructional tool has been severely limited. Only a few applications, like distance offering of courses in rural settings by closed circuit television and construction of instructional videos have gained wide acceptance. Instead, television has primarily been used as an entertainment device instead of as an instructional tool.

With television, show offerings had to compete with a limited number of advertising dollars to support the program. The internet does not have the problem of having to generate of advertising dollars to support academic sites yet. This means that professors can create and offer what they wish without having to generate outside funding. This should keep the "lowest-common-denominator" programming as evidenced in the television industry out of Web-page instructional materials. However, there is another "lowest-common-denominator" approach that is showing up in academic Web-pages. Faculty members in general are not expert in the

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technologies that are available for use on the Web[5]. Instead of developing strong materials, we often use off-the-shelf applications that are not as powerful or as engaging for students to use. An example is that almost every course now has an online syllabus, while very fewer have streaming video or interactive chat rooms[9]. The easier the technology is to use, the more likely it is to show up in use.

It is also extremely time consuming to develop online course materials[10]. Very few faculty have the time and resources to create new materials because of the time needed to develop these types of presentations. However, it only takes a few minutes to create an online syllabus with a program like Frontpage.

III. Problems With Web-Based Course Offerings

There are three types of Web-based instructional tools we will discuss now so that we can highlight some of their limitations. We start our discussion here so we can move beyond these limitations before we present the methodology behind our Web-based offering.

Streaming video is often used in Web-based course offerings because it is relatively easy to generate with adequate support from trained individuals. However, it takes more time to prepare for a streaming video course. The advantage is that the materials can be used several times without having to redo the preparation and generation phases. Also, students can review the lectures repeatedly, which they cannot do in a traditional lecture.

The major problems with streaming video involve time and the way that streaming video is used by students. Students that are able to view the streaming video in real-time and that are able to ask questions of the professor get all the benefits of being in a traditional classroom without having to physically be in the same location. However, streaming video is often used by students who may not have access to real-time support. The distance learners must often do without the interactive components of a traditional course and passively watch the streaming video. To address this issue, faculty have offered online support or chat forums for students using time delayed streaming video and have commented that it is very difficult to offer technical and informational support when students want it available[11]. The question must be asked: Is passively watching a streaming video of a lecture effective for teaching engineering course materials? Students may feel they are just watching another television program and give it the amount of attention that television normally requires.

Another way that faculty often use the Web in their courses is to post class information online so that students can access it at their leisure[12-13]. Syllabi are most commonly posted, while other postings include homework solutions, class notes, grade information, and other course specific materials. Posting notes in their entirety after a lecture may be less useful for students than it may first appear. Students that can get complete notes without going to lecture often will skip the lecture. There is little incentive for them to attend a lecture when they can just click on a button and instantly get the notes. However, notes that are posted on the Web prior to a lecture can be useful if there are significant areas where students will have to fill in information from the lecture. This format allows students to preview the lecture materials, but also engages them during class as they fill in information. Also, they are not spending large amounts of time

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copying information that is not critical. Instead, they are only required to copy the key points or derivations and can read the background information from the printed notes.

Chat rooms for courses allow students to have a dialogue about course materials on the Web[11]. The advantage is that students from distance learning locations may be able to communicate with students who are in other locations. However, chat rooms for courses have several problems. First, creating and maintaining them can be extremely time consuming. It is also time consuming to manage the information that is being added to the chat room. Ideally, a faculty member would be monitoring the chat room and interjecting corrections and suggestions as students discuss complex material. Another problem with chat rooms occurs primarily in lower level courses because all students do not have the same comfort levels with using computer technologies[1]. It has been hypothesized that some students are statistically less likely to use on line computer-based materials than others, which would lead to them being excluded from a significant benefit of a Web based course.

So far we have seen that the Web can be used to augment certain formats of presenting information to students. The full benefits of Web-based instructional materials, though, seem to accrue when students are also able to take advantage of real-time discussion during interpersonal interactions[14]. When the Web is used as a surrogate to replace face-to-face real-time interactions, as opposed to being used as a supplement to course materials, then the benefits of Web-based materials come at the cost of other instructional benefits. There just may not be a gain in learning over traditional methods. At least one study[4], has shown that students in a Web-based course performed worse than their counterparts in either a traditional lecture format or using correspondence couse materials. Other studies have shown the opposite, but they admit that students studied more when they were using the Web-based materials[15].

IV. Developing Strong Web-Based Examples

The goal of this work was to use the strengths of combining a Web-based component with a traditional lecture course to teach introductory problem solving skills to chemical engineering students. The benefits of using the Web as a supplement to a traditional course are shown in Figure 1. First, students can work at their own pace. They can also have interactive materials that respond to student choices, which is not possible in a printed book format. The interactivity can take many forms, but should be used to provide feedback about student progress in understanding the material. Finally, formats for engaging students with the material that are not available in static printed books are also possible online.

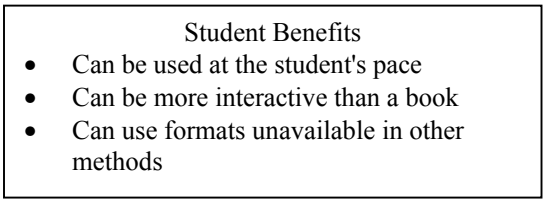

Figure 1 - Benefits of using Web-based materials to supplement a traditional lecture course.

The strengths just described were used to create Web-pages that explain how complex problem solutions are generated from a basic knowledge of chemical engineering principles. There are approximately 40 students in this class each fall semester, with half of the students

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being in the honors program. Half of the students are female, 15% are non-traditional, which is defined as being older than 25 years old, and 15% of the students have English as their second language. The students are mostly sophomores that have not had much exposure to complex problem solving skills in their prior classes and they may have relied heavily on "plug and chug" methods of problem solving in order to survive their first year. They may get lost in the problem solution and cannot put "unrelated information" together to synthesize a route to the answer they need.

The goal was to create a series of Web-pages that would lead students through the fundamentals of organizing complex problem solutions. The materials would necessarily begin with very rudimentary concepts like the notation that would be used during problem solutions. The materials would then get progressively more complex as students built a problem solving framework. Several realizations were made as we began developing the Web-based tools, which are shown in Figure 2.

- materials must be interactive
- materials must be different from lecture and book
- materials should reach students with different learning styles
- materials must start with the very basics

Figure 2 - Characteristics of Web-based materials to enhance traditional formats.

First the materials must be interactive so that students can receive feedback on their learning progress[16-17]. The materials must be different from the lecture or the book[18-19]. If the materials are identical to information that students can get in other formats, then students will only use one of the formats. Materials can also be used to instruct students that have different learning styles. In a lecture, we can only present materials in one format at a time, but Web-based materials can be varied among learning style formats so that students can choose to use the ones that benefit them most.

The Web-based materials in this project were coded primarily in HTML and JAVASCRIPT. The HTML code contains the structure and format of the Web-page while the JAVASCRIPT language allows one to add interactive features that will provide feedback to the students. Several programs were used in developing the materials and include various text editors, Microsoft Word, Excel and Frontpage, and Flash. The best available tool for accomplishing the desired Web-effect was used in each instance. Faculty wishing to create a course with few Web-programming skills could consider using one of the many tools that have been created to support Web-course development instead of doing the programming themselves. A recent review of these programs discusses the strengths and weaknesses of most of the major available tools[10].

Almost all of the Web-based materials for this project were developed by undergraduate students. The students who participated in the project were selected for several reasons. Several students had extensive HTML experience and they expressed an interest in the project. However, other students participated because they had struggled with the course materials during a previous semester and wanted a way to review the materials during the summer months. These students were either working for credit or for pay from funded research projects

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Students commented that they benefited in different ways from working on the materials for this project as they created the Web-based examples. They said they had strengthened their computer programming skills and were no longer intimidated by new computer programs. A typical student would learn five new computer programs as they developed their examples to post to the Web. They also said they had increased their understanding of the introductory chemical engineering materials because they had to present the information in a variety of formats. Some students also seemed to enjoy developing the pedagogical approach to presenting their problem solution. Thinking like the professor gave them some insight into the issues professors must deal with in order to successfully teach students.

V. Examples of the Materials

A static format like this paper cannot really demonstrate the materials that were developed. However, we will show several examples of screen shots from the Web-pages and describe the methodology and purpose of the pages. Materials are also available at: http://www.che.arizona.edu/Directory/Faculty/Blowers/problem/KeepingTrack/index.htm

Figure 3 shows a screen shot of a very basic page that describes the notation we use in the Webpages and has an example for the students. Students are asked to choose one of the radio buttons from the multiple choice set after they read the short example. When a student clicks on an incorrect button, a new alert box pops up that gives feedback to the student about their choice as shown in Figure 4. A correct answer allows the student to move on to the next question.

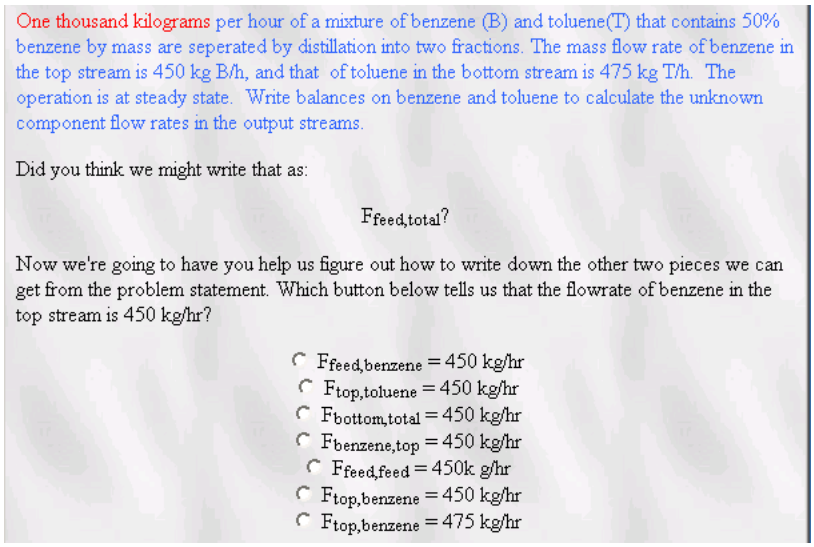

Figure 3 - A sample screen-shot showing how multiple choice questions can add interactivity to engage students in learning how to solve problems.

We vary the format from one question to the next or from one example to the next so that students don't get bored with the presentation of the materials. Sometimes, a student needs to click on a radio button, a clickable button, or some other multiple choice selection tool. Other questions ask the students to calculate a number or series of numbers and then enter them into text boxes so their answers can be checked. Varying the format requires the student to be paying at least minimal attention to the materials or they can not proceed through them. Unlike a book where a student can just turn the page to move on regardless of understanding, students must be much more active to get through these materials.

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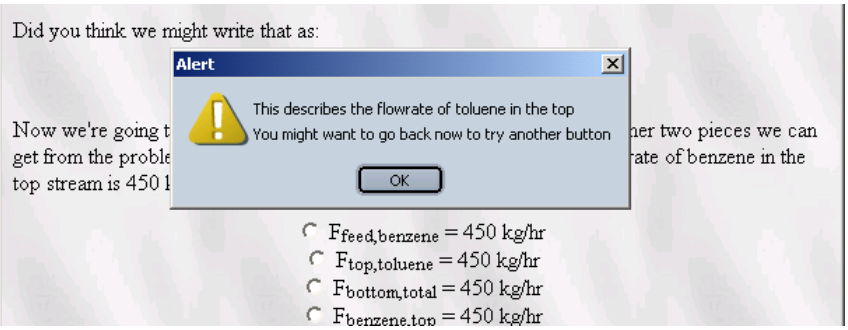

Figure 4 - A sample of feedback given to students when they get an incorrect answer.

We mentioned earlier that one of the advantages of using the Web to present materials is that formats may be available for teaching to different learning styles. This is needed because informal surveys of our freshmen engineering class show that ninety percent of the students are visual leaners. However, lecture materials are verbally presented and then written on the board, heavily relying on alphanumeric representation. Visual students may have a difficult time seeing the relationships between different ideas because all of the presented material was relayed through verbal methods. In Figure 5, we show a page that is highly visual. As students move the cursor around, different parts of the page light up to show how information from a figure is related to information in a table and to the equations that could be used to describe relationships between the variables. This type of changing display is not possible in books so the visual student may find it more useful than a traditional text book.

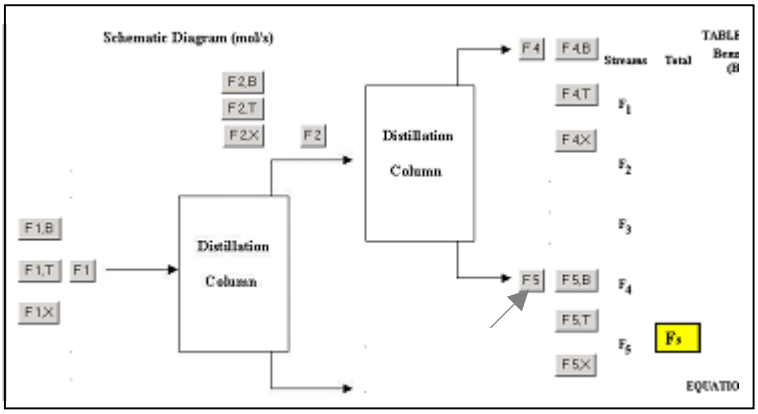

Figure 5 - A cropped visual learning example. The grey arrow shows where the mouse would be to have the yellow box appear. Information changes between the table in the upper right, the equations on the lower right, and the diagram as the student moves the cursor.

VI. Testing the Materials

The Web-based materials went through two levels of testing. First, a high school student worked through the example problems to identify any omissions that may have made it difficult to move through the examples. The student was able to proceed fully through all of the examples without having had the course, simulating a worst-case scenario of having to quickly introduce a sophomore college student to the material.

The second trial involved students in the sophomore level chemical engineering course. Students who did poorly on the second exam were required to work through the Web-based materials and generate a list of questions they still had after they completed the examples. The examples covered basic problem solving skills that would be needed for the rest of the semester. Student scores on the following exams improved dramatically, by almost 20 percent, after the

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students had worked through the Web-based examples. Students seemed to be able to make it much farther through the exam questions once they had worked specifically on understanding problem solving skills.

One student commented, "I learned a lot from the course pages. I was having a hard time following the methods we were using in lecture because I'm just not that fast at keeping up in English. The Web-pages allowed me to go slower so I could learn the details." This student was on the road to getting a failing grade in the course, but brought their grade up to a C after using the Web-pages. They are now working on this project to program their own example problem so others can learn from it. This should strengthen their computing skills, increase their problem solving confidence, and review the knowledge they received in the course.

VII. Conclusions

Web-based instructional materials should be used to supplement offerings or to increase educational opportunities for those who cannot attend traditional classes. Distance learning is one scenario where Web-based materials have been used successfully when face-to-face interactions are not possible. However, real-time support of distance learning students as they access the materials makes learning much more effective. When the Web-based materials are used to supplement course offerings instead, they must take advantage of the Web-features that make them more useful instead of just replacing traditional tools. Interactivity and the ability to present materials in non-static formats are just two ways to make supplemental Web-based materials useful.

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