Development and Use of a Web Site with Multimedia Contents as a Complement to Traditional Unit Operations Courses

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ABSTRACT: The Unit Operations Laboratory offers 2 courses in unit operations. One is a 2-semester course for chemistry and food engineering students that is more demanding because it considers more unit operations and places more emphasis on solving exercises. The other is a 1-semester course for chemistry and pharmacy students that considers fewer unit operations and is more descriptive. We have developed a web site with multimedia contents and interactive exercises, mainly for students with fewer abstract and mathematical learning styles who prefer visual, spatial, and hands-on learning situations. For the development of multimedia elements, the more common unit operations that have greater learning difficulties related to the course audience were considered. For the course oriented to chemistry and food engineering students, the unit operations considered were size reduction, mixing of liquids, distillation, microfiltration, and solid-liquid extraction. The evaluation of the site consisted in gathering the students' opinions but did not measure the impact of learning. The results showed that the students have a good opinion of the design of the web site and that the multimedia elements included are useful teaching tools.

Introduction

The Unit Operations Laboratory offers 5 compulsory undergraduate courses and 1 elective course taken by 320 students per year. All the compulsory courses include laboratory practice and exercise seminars. There are 2 types of unit operations courses. One is a 2-semester course, called Unit Operations I and II, for students of chemistry and food engineering, and the other is a 1-semester course, called Unit Operations, for chemistry and pharmacy students. A prerequisite for these courses is a physical chemistry course, which includes the study of the principles of thermodynamics. The unit operations courses are prerequisites for the pharmaceutical technology, industrial chemistry, and process engineering. The 1-semester course oriented to chemistry and pharmacy considers fewer unit operations, is more descriptive, and places less emphasis on the resolution of numerical exercises. The 2-semester courses oriented to chemistry and food engineering students are more demanding because they consider more unit operations and place more emphasis on the resolution of exercises. All the courses have a traditional lecture format, seminar sessions devoted to solving problems, and laboratory experiments. This classic approach has a number of inherent problems that include passive learning, difficulty in applying the concepts learned in the course to real-life problems, and little or no responsibility of the students for their self-learning (Reddy 2000). Over the past 2 y, some modifications have been introduced, specifically in the course for chemistry and pharmacy students, because it has a larger number of students with low motivation for the subject and some learning difficulties. The modification was to develop a CD-ROM oriented to the applications of unit operations in the pharmaceutical industry (Tapia and others 2002). The next logical step for complementing our traditional course format was to develop the unit operations web site. The purpose of this article is to describe how we set up a web site with multimedia content and interactive exercises mainly for students with fewer abstract and mathematical learning styles who prefer visual, spatial, and hands-on learning situations.

Materials and Methods

The design of a unit operations web site considers including the following items in each course: course program, printed materials in PDF format for seminars and laboratory activities, and a multimedia section (videos, animations, and exercises in spreadsheet format) developed to support the course content. Additionally, a page was designed to include relevant external web pages that give information about

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international and national regulatory institutions, equipment suppliers, and technical journals.

**Software selection**

The software used in this project is the 1 most commonly used for web site production with multimedia content. The web page was made using Dreamweaver (Dreamweaver ver.5.0, Macromedia, Inc., Santiago, Chile). The animations were designed using FLASH (FLASH MX Macromedia, Inc.). The movies were created using Director (Director Ver. 8.0, Macromedia, Inc.). The videos were edited with Premiere (Premiere Ver. 5.0, Adobe Systems Incorporated, Santiago, Chile), and the exercises were developed in Excel (Microsoft Excel 2000, Universidad de Chile, Santiago, Chile).

**Selection of multimedia elements and design criteria**

It has been stated in the literature that students with fewer abstract and mathematical learning styles prefer visual, spatial, and hands-on learning situations (Cole and Todd 2003). Thus, the web site contents were developed mainly for students with fewer abstract and mathematical learning styles who prefer visual, spatial, and hands-on learning situations.

For the development of multimedia elements, the more common unit operations, which involved more learning difficulties relative to the course audience, were considered. Thus, the course for chemistry and pharmacy students considered the common unit operations involved in pharmaceutical dosage form production and in the main services used in this industry (tablets, sterile and nonsterile liquids, and purified water production). For the course oriented to chemistry and food engineering students, the unit operations considered were size reduction, mixing of liquids, distillation, microfiltration, and solid-liquid extraction.

The animations developed were devoted to those topics that are difficult to comprehend by the students because they require relating real multistep production processes with abstract representations, which allow numerical calculations through systems of equations or graphical methods. It has been said that when conceptual computer animations are used in conjunction with chemistry lecture demonstrations, students are better able to make connections between the microscopic, macroscopic, and symbolic levels of representation (Burke and others 1998).

The incorporation of videos in the web site made it possible to show video clips of the common pharmaceutical processes developed in our local industry. These videos produce a high level of student motivation because they make it possible to view direct applications of teaching in their future professional activity.

Spreadsheet programs are used in many chemistry classes as tools to assist in the conceptual understanding of chemistry and for carrying out complex chemical calculations. Recently, the principles of acid-base equilibrium were explained using an aquatic chemistry spreadsheet (Kim 2003). The use of the ASTutE (Automated Student Tutorial Environment), to teach how to solve material balance problems to Chemical Engineering students, has been described (Edwards and others 2000).

**Results and Discussion**

**Subjects considered in the development of multimedia**

Microfiltration. Among the different unit operations used in the pharmaceutical and food industry, one that has undergone important changes is filtration, particularly filtration processes using membranes, the most important of which are microfiltration, ultrafiltration and reverse osmosis. These technologies are used for sterilizing, clarification, prefiltration, separation, concentration, and desalination.

The importance of this subject is very relevant for the production of products for injection, eye solutions, sera, vaccines, and purified water. Each sterilizing filtration process must be submitted to integrity tests (bubble point test, diffusion test) (Chrai 1986).

Also, microfiltration is widely used in the wine industry. Wine contains a large amount of fine particles in the range of 3 to 10 μm, which correspond mainly to yeasts, bacteria, pigments, tartrate crystals, and pulp. The purpose of filtration is to eliminate all these particles from the wine. The filtration process considers 1st a cake filtration followed by microfiltration. (Molina 1992; Gillmore 1999). Although microfiltration is currently a widely used technique, no published reports are available of educational efforts to teach the basic principles and techniques of microfiltration for developing microfiltration processes properly. In our country, winemaking has improved very much over the past 20 y, and there is great interest in the subject in our society. Therefore, we have considered that wine is a good material for teaching the basis and technical procedures of microfiltration. Some articles related to the chemistry of winemaking and the chemistry of wine have been published (Church 1972; McClure 1976; Crews 1977; Horn 1977; Gadeck 1982; Lee and others 1986), but none are specifically focused on teaching the use of microfiltration in the wine industry. Lately we have been developing some practical activities and an interactive CD-ROM in which, using the winemaking process, we are teaching the basis of microfiltration. Part of this material as FLASH animation has been placed in the web site. We have developed animations of bubble point and diffusion integrity tests (Figure 1). These animations show that the bubble point test measures pressure and the diffusion test measures gas rate. They also show that the bubble point test is applied to small filtration areas and that the diffusion test is applied to large filtration areas that are obtained using cartridge filters. Figure 2 shows the use of microfiltration in the production of sterile pharmaceutical products. The use of microfiltration as prefiter, sterile filter, and vent filter has been stressed. A videoclip of a real production process of sterile solutions (eye solutions) was placed in the website. The videoclip shows the application of bubble point tests in the...
sterile filtration step. Figure 1, 2, and the videoclip should be useful for students to make the connection between abstract representations and real multistep production processes. Also, a drag-and-drop type puzzle for the production of sterile purified water for pharmaceutical use by reverse osmosis has been included in the web site. In this puzzle, the students must assemble in a sequential form the unit operations involved in the process. When the puzzle is completed, an animation of the process is displayed (Figure 3). This exercise offers a hands-on learning situation for the students.

**Distillation**

Distillation is one of the most widely studied unit operations and one of the most important in the chemical industry. It is taught in undergraduate general or organic chemistry courses as a laboratory separation procedure (Taber and Weiss 1998), in physical chemistry courses as part of phase theory in liquid-vapor system, and in unit operations courses in which the design of fractionating columns is described. Also, distillation has a very attractive history, very closely related to the development of chemistry (Liebmann 1956).

Because our faculty is a faculty of sciences and not a faculty of engineering, the approach to this subject is through laboratory experience as a liquid-separating technique. In our teaching we try to point out the difference between differential distillation or Rayleigh distillation developed in the laboratory, and simple equilibrium distillation or flash distillation used in the petroleum industry, stressing that at the industrial level, continuous fractional distillation predominates. In relation to industrial applications of this unit operation, we highlight those most widely used in Chile: differential simple distillation as a process in the production of pisco (a type of distilled liquor very common in Chile) and its analytical application in the determination of alcohol content in the wine industry, and steam distillation as an extraction procedure for essential oils from plants, especially in the production of eucalyptus and lavender oils, and its analytical application in the determination of volatile acidity in wine. With respect to industrial continuous distillation, the basic principles of fractional column design are taught based on the McCabe-Thiele method. This aspect shows serious learning difficulties. The difficulties for students to put together the principles of liquid-vapor equilibrium with practical aspects of distillation have been described in the literature (Goedhart and others 1998), so some analogies have been introduced to explain the principles of fractional distillation (Mukesh 2001). That is why we developed an animation that attempts to help the students make the connection between the real multistage separation processes and abstract representations that allow numerical calculations through systems of equations or graphical methods (Figure 4). The basic components of the continuous fractionating column are seen by rolling the mouse over buttons 1 through 7. The liquid-vapor equilibrium at each plate is shown as an animation by clicking button 1. The visual representation of this equilibrium can be related to the basic McCabe-Thiele fractionating column design equations by clicking on the McCabe-Thiele button.

**Solid-liquid extraction**

Solvent extraction of active substances from plant or animal materials is a very old technique used in pharmacy; this technique also is widely used at the industrial level in ore extraction and oil extraction from seeds. For our students, it is important to know the laboratory extraction technique, the methods for calculating simple multiple extraction (Soxhlet extraction), and continuous multistage extraction (industrial procedure), and the equipment used in industry. To support our classes, seminars, and laboratory activities, we have developed an animation from a representation of a soybean oil production plant (Figure 5). In this animation we show that the extraction operation is always preceded by size reduction and shape modification steps, followed by solute separation from the solvent by evaporation/distillation. Also, the countercurrent direction of the solid and liquid phases in the Bollman extractor is shown, so it is easier to relate the industrial extractor operation with the flow sheet used to apply the calculation procedures using mass balance (Charm 1971).

**Mass-balance teaching using spreadsheet**

Problem-based learning (PBL) is an educational method focusing on the acquisition, synthesis, and appraisal of knowledge by...
actively working through problems. The computerized PBL materials may serve as substitutes for facilitator-led group sessions, thereby reducing personnel requirements for schools with large class sizes (Abate and others 2000).

Oral solid dosage forms are one of the most important pharmaceutical dosage forms normally produced, with tablets being the most common. The traditional method for producing tablets normally involves 2 size enlargement processes in sequence: a granulation of the fine particulate drug, often milled with a filler, followed by compaction of the granulated powder (Alderborn and Wikberg 1996). The exercises were based on tablet manufacture by wet granulation. They were divided into the following 3 sheets (Tapia and others 2004):

**Mass balance**

In this section, the user can define the components of the formulation, their percentages in the formulation, the weight of the tablet, and the batch size. The mass balance of the granulation step is shown, and the user must define the concentration of the binding solution, which means defining the water used in the batch production. The questions are about the drying granulation step of the process. The user is asked to answer questions about the mass of water evaporated and the mass of dry granulate obtained for a certain percentage of residual humidity required for the dry granulate, which is also defined by the user in the range 1%-4% humid basis (Figure 6a).

**Drying.** This section shows the drying process for granulates developed in a fluid bed dryer, where the air used is heated with saturated steam. The user must define the drying conditions: room temperature (°C), input air conditions such as humidity (kg of water/kg of dry air) and temperature (°C), output air conditions such as humidity (kg of water/kg of dry air) and temperature (°C), and specifications of the boiler used for the production of saturated steam. The questions are related to the following aspects: kg of dry air used, m³ of air under input conditions, kcal required for air heating, kg of saturated steam required, and cost of steam per batch (Figure 6b).

**Optimal mixing time**

This section is related to the process step in which the dry granulate is mixed with the lubricant in a twin-shell blender. One of the most important operations in tablet manufacture performed with basic equipment, which is very common in Chile, is to determine the degree of homogeneity through the “mixing index.” The objective of this section is to teach how to select the appropriate tracer and calculate the mixing index. The questions are as follows: Define which component of the formulation is suitable for use as a tracer; calculate the theoretical standard deviations at zero time; calculate the mixing time using the table of data for the selected tracer. By clicking on the plot base the user can compare the mixing index over the time curve obtained with the correct curve (Figure 6c).

**Preliminary web site evaluation**

The web site was publicly launched on May 2003. To gauge the interest and acceptance of the site, students were given the site address [http://www.ciq.uchile.cl/operaciones/](http://www.ciq.uchile.cl/operaciones/) in the Fall 2003 semester. The multimedia elements located in the web site were used in the lectures, and the students were motivated to use them in their home or at the faculty to help in their learning. During the May to November 2003 period, the site was evaluated by the students through the electronic surveys located in the web site. The survey asked questions about the design quality of the web site and its usefulness as a tool to improve the teaching in unit operations courses. The number of surveys received was 67. The total number of students that took our compulsory courses during this period was 188. Therefore, the percentage of students who answered the survey was 36%. The results of the surveys are shown
in Table 1 and 2, Table 1 shows that the more frequent answer about the ease of navigation was “easy” and the more frequent answers related to the design quality was “good.” Less than 10% of those surveyed considered the design quality “poor.” Table 2 shows the results of the questions related to the usefulness of the web site as a teaching tool. The more frequent answer was “very useful.” Considering the answer distribution, 93% of the student considered it very useful or useful to have a web site. More than 90% of the students considered it useful or very useful to have animations, video, and exercises in spreadsheet format available on the web site. More than 80% of the students considered it useful or very useful to have the course materials in PDF format. These results pointed out that the students have a good opinion of the design of the web site and that the multimedia elements included are useful as teaching tools. The effectiveness of this web site to increase the performance in the course scores have not been evaluated.

Table 1—Results of survey about the design of the web site

<table>
<thead>
<tr>
<th>Questions</th>
<th>Distribution of answers (%, n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of navigation</td>
<td>76% Easy 16% Medium 8% Difficult</td>
</tr>
<tr>
<td>Design quality</td>
<td>76% Good 18% Medium 6% Poor</td>
</tr>
<tr>
<td>Video quality</td>
<td>66% Good 25% Medium 9% Poor</td>
</tr>
<tr>
<td>Animation quality</td>
<td>70% Good 22% Medium 8% Poor</td>
</tr>
<tr>
<td>PDF document quality</td>
<td>67% Good 24% Medium 9% Poor</td>
</tr>
</tbody>
</table>

Table 2—Results of survey about the usefulness of the web site

<table>
<thead>
<tr>
<th>Questions</th>
<th>Distribution of answers (%, n = 67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is it useful to have a web site for Unit Operations Lab?</td>
<td>76% Very useful 21% Useful 3% Useless</td>
</tr>
<tr>
<td>Is it useful to have animations and videos to support the classes?</td>
<td>69% Very useful 25% Useful 6% Useless</td>
</tr>
<tr>
<td>Is it useful to have the print material courses in PDF format?</td>
<td>61% Very useful 26% Useful 13% Useless</td>
</tr>
<tr>
<td>Is it useful to have exercises in spreadsheet format to support the seminars?</td>
<td>70% Very useful 25% Useful 5% Useless</td>
</tr>
</tbody>
</table>

Conclusions

We have developed a web site with multimedia content and interactive exercises mainly for students with fewer abstract and mathematical learning styles who prefer visual, spatial, and hands-on learning situations. The animations developed included the subjects of microfiltration, distillation, and solid-liquid extraction, which are difficult for students to comprehend because they require relating real multistep production processes with abstract representations that allow numerical calculations through systems of equations or graphical methods. These animations can help students learn information much better than use of typical classroom instruction. The incorporation of videos in the web site produced a high level of student motivation because it makes it possible to visualize direct applications of teaching in their future professional activity. The spreadsheet exercises included in the web site can help students learn how to solve material balance problems using real data from industry. The preliminary web site evaluation of the site showed that the students have a good opinion of the design of the web site and that the multimedia elements included are useful as teaching tools.
Acknowledgments

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References


