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The Web as a Tool for Supporting Student Learning in Chemical Reaction Engineering*

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The aim of the project described in this paper was to increase motivation among students for the advanced course in Chemical Reaction Engineering and thereby increase the learning outcomes for the subject. This was done by making selected parts of the course available and more attractive on the WWW and by developing and improving types of assignments that emphasise a more profound understanding and interpretation of chemical reaction phenomena. First, the methods used in designing the web pages are presented. The second section includes a description and structure of the selected parts of the course that were included in the web pages. The assignment part, in particular, is described in more detail. In the third section the students' approach to using the web pages is discussed. The results from this project are very promising and further development and evaluation will be performed.

INTRODUCTION

Chemical Reaction Engineering (CRE) is a major fourth year course (four credits, about sixty students per year) at Chalmers University of Technology [1]. The students consider the course to be one of the most difficult, probably due to its combination of applied mathematics and physical and chemical phenomena. Most of the students are quite unfamiliar with this kind of practical application of relatively advanced mathematical models for chemical processes and their dynamic nature. A general concern, not unique to this course, is how to get students more actively involved in the lectures and exercises. It should be mentioned that in spite of these concerns this CRE course is much appreciated by the students and is one of the most popular. Since this course is part of an international Master's programme called Environmentally Sustainable Process Technology (www.che.chalmers.se), all course material and teaching are in English.

Lectures provide an overall introduction to the current topic in the subject, and present the fundamental principles behind the important phenomena. The aim of the exercises is to teach the students problem-solving methodology and to enhance their problem-solving skills. During lectures and exercises, the majority of students are quite inactive however and have no dialogue with the lecturer. On the whole, there is only a transfer of written material from the blackboard to students' notebooks, without any critical analysis on their side. In our opinion, two-way communication is necessary in order to gain a higher level of learning. This lack of communication might be due to the fact that the students, especially in the beginning of the course, have not enough knowledge for a profound understanding of all elements of the actual problem. During the exercises, there is usually no time for a comprehensive repetition of the theory previously treated in the lectures and the time for self-learning is limited. It is important to note that the above-mentioned concerns are not in any sense unique to the course in CRE. The outcomes of this project should therefore be of interest for other problem-oriented courses.

The aim of this project was primarily to increase the motivation of students studying the subject by making selected parts of the course available and more attractive on the WWW. General course information, course schedule, laboratory guides, individual exercises, projects and research seminars were all avail-

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able on the web. These parts will be presented in more detail later. As can be seen below, the goal was not to reproduce the entire course material on the web, but to gain some pedagogical benefits in terms of increased learning outcomes by exploiting certain advantages offered by computers and the web.

METHODS

System description

The pages were displayed on a local web server using O'Reilly Website 1.1e, free for educational use [2]. The web server was a 120 MHz Pentium PC with 32 Mb of RAM. The pages were created and edited using Microsoft FrontPage 97 [3]. Old documents were imported from Microsoft Word and converted to HTML-code in Microsoft FrontPage 97. The number of visits and average visit time were calculated using Marketwave Hit List [4]. The students had access to computer rooms with 486 and Pentium PC computers. The software used was Netscape Navigator 2.0 [5] and MATLAB [6] on Windows 3.1.

Almost all information about the course was displayed on the Internet and very little was given in paper form to the students. Figure 1 describes the main structure of the web pages. The following information was displayed:

- New information
- Course description
- Schedules
- Assignments
- Descriptions of course projects
- Laboratory exercises
- Transparencies from seminars about current research at the university and in the industry
- Answers and solutions to final exams
- Introduction to MATLAB and on-line links
- Diploma work related to the course

Apart from the assignments, none of the information was interactive. Some of the items, and the approach to running the project, are described below.

General information

All information of a general nature, such as course information, description of projects and laboratory exercises and solutions to old final exams, were displayed on the web. One obvious advantage is that the information can be updated during the course. Transparencies from tutorials were scanned and displayed on the net shortly after their initial use. The course was also related to our research and industrial activities by linking the course information to, for example, diploma work.

Course information

The course description contained the following information:

- Purpose of the course

  This course provides knowledge in chemical reactions and transport processes, which is essential in selecting and *dimensioning* suitable apparatus for catalytic processes.
- Content and organisation
  - Mass and heat transport coupled with chemical reactions
  - Film transport, pore transport, and gas-liquid reactions
  - Design of catalytic processes
  - Current research projects with industrial applications

  The course consists of lectures, research seminars, exercises, experimental work and a calculation project. The exercises include obligatory assignments to be handed in. The experimental work comprises an experimental and a seminar part, with the aim of illustrating difficult aspects of the course. The calculation project is intended to train students to structure a major design problem and to solve it with computer assistance.
- Course literature

  Compendiums published by the Department.
- Examination

  A written examination and the approval of assignments, experimental work and project.

Assignments

Four individual assignments were included in the course, each concentrating on a particular topic. The students solved the assignments in the computer laboratories, to a great extent during the two hours that were reserved for each assignment. Two of the assignment (K and G in Figure 1) were handed out in paper form (*paper assignments*), while the other two (E and F) were only available on the web pages (*web assignments*). An introduction to each assignment was available on the web, replacing the guided introduction held in previous years. Added to the introduction were some helpful hints to parts of the assignments that had been experienced as difficult in previous years. The students

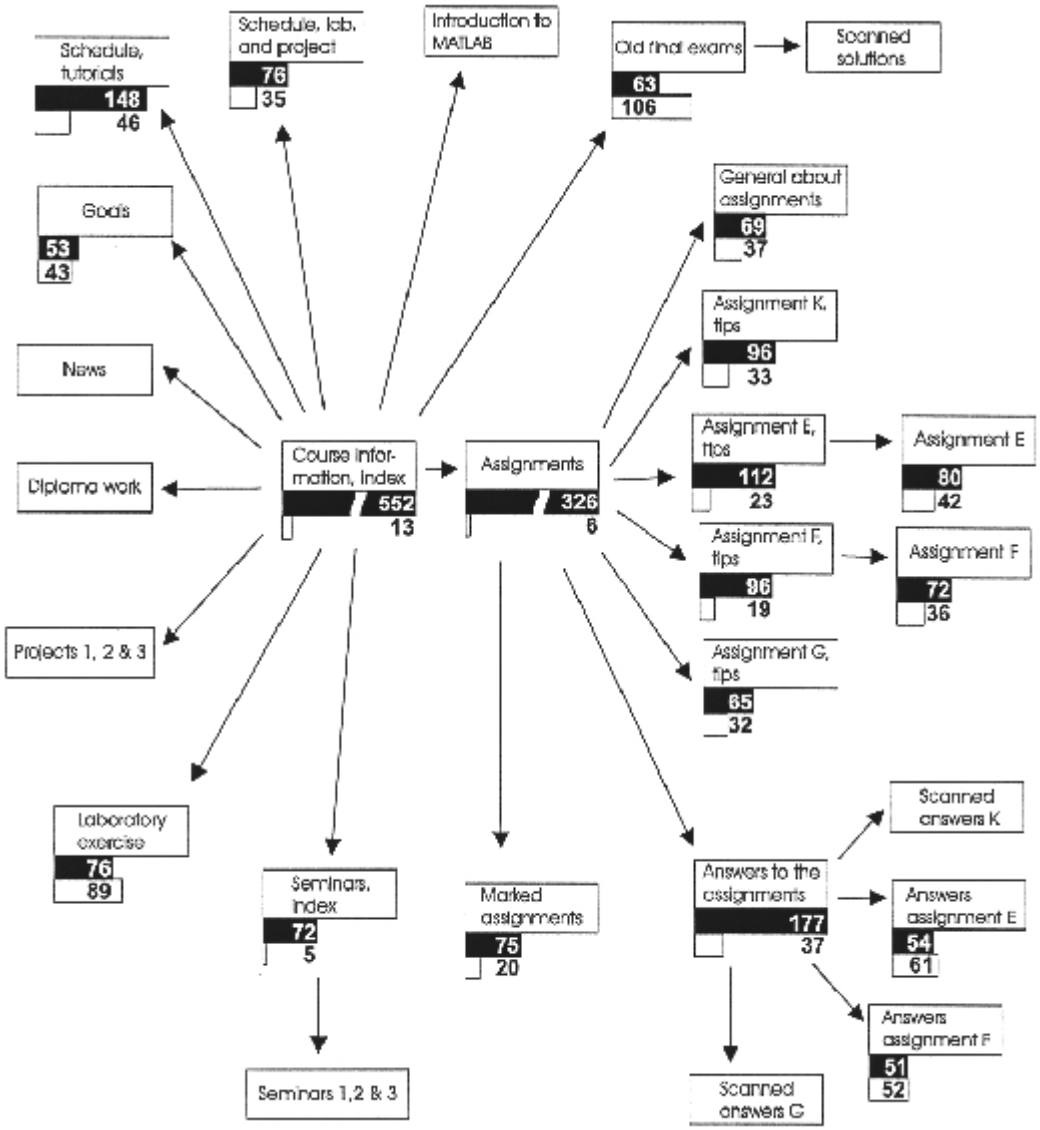

Figure 1: The main structure of the web pages. Cross-links are not shown. The black bars show the number of visits to a page and the white bars the average time in seconds that the page was viewed. For pages with less than 50 visits and pictures, ie scanned transparencies, the number of visits has not been shown.

may request these hint pages when needed.

Every assignment also comprised a number of discussion questions that students had to discuss while formulating their answers. For each assignment, an answer to one of these questions was to be turned in as well. The students were informed that these theoretical discussion questions were a measure of their deeper understanding of topics covered in the assignments.

One of the goals of this project was to make students use the computer as a natural tool in problem-solving. The assignments handed out in paper form were already well-adapted to the use of computers, while the other two assignments were completely adapted to the web and to MATLAB. This goal was attained by requiring the students to exemplify the effect of different variables on the process object functions, eg the effects of temperature and flow rate changes on reaction rates and mass transfer limitations in different graphs. This would not have been possible without computational tools.

The structure of the web assignments is shown in Figure 2. The students start at the main form, where some hints regarding the solution are available when requested. From the main form, the student may choose to download their individual assignment (1), or go to the form with answers for the assignment (4). The students received their *web assignments* by entering an arbitrary personal code. The personal code was checked in a CGI-program written in Microsoft Visual Basic 4.0 (3). The program created an HTML file presenting the assignment. The students were re-

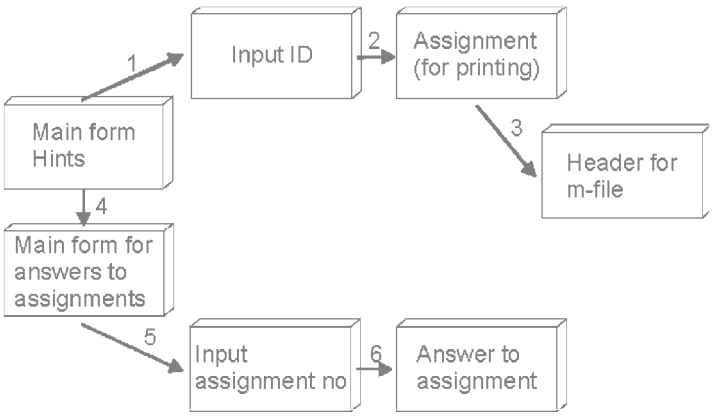

Figure 2: The structure of the web assignments.

quired to print out this HTML document and include it together with their solution. The individual assignments had already been prepared in MATLAB and were available as data in a text file for the CGI-program. MATLAB programs are written as m-files, MATLAB's file format. The CGI-program created an m-file header for the students to download, containing variable definitions and values for their assignment. The answers to each individual *web assignment* were available as tables and graphs via the number of the assignment. Another CGI-program (6) combined previously calculated data from a text file with graphs prepared in MATLAB.

The student could download a MATLAB file containing data common to all assignment with blanks for their own data for the *paper assignments*. The answers to the *paper assignments* were available as scanned pages.

When the students had completed an assignment, they turned in the complete solution, as in previous years, with the computer program, a printout from execution and the answer. When the assignment had been evaluated, the students could get information on the web, via their personal code, as to whether their assignment had been approved or not.

Seminars

Three seminars with invited speakers from industry and researchers from the university were held during the course. These seminars illustrated practical use of the course in different areas, such as catalysis, chemical reaction engineering and biotechnology. The transparencies used by the invited speakers were published on the web. The transparencies that were available in electronic format, eg made in Microsoft PowerPoint, were easily converted to web pages. Parts of the transparencies were only available as hard copies, and some of these were scanned, edited and presented on the web. Titles of the seminars are given below:

- Biotechnology: Fermentative Ethanol Production
- Catalysis: Research, Development and Industrial Applications:
  - History of catalysis
  - Car exhaust catalysis
- Monolithic Catalysts: 2-Alkylanthrahydroquinone autooxidation - and other stories

News

A page that displayed news in and about the course was created. This page was of great importance to the students because the schedule was sometimes changed and errors in the assignments were found. Another reason was the continuous increase of information during the course. Typical information included:

- *An errata list for course compendium can be downloaded as a Word 6.0-file and in rtf-format. A printed errata list is also available at the department.*
- *The calculation hints part of the mass transfer lab has been updated, so that references to Yoshida's correlation are given.*
- *Rooms for lectures, calculation exercises and projects have been changed. Please check our web pages instead of paper course PM.*
- *Some assignments are marked 1997, but they do not differ from this year's assignment so you may safely go ahead and solve them!*
- *Course PM and material necessary for the course are now available on the web.*

RESULTS AND DISCUSSION

The web pages

As well as the structure of the web pages, Figure 1

shows the number of visits and average visit time for the pages most frequently requested during the course. The most frequently visited pages are the ones with links to other information, eg *Course information index* and *Assignment index*. The schedules that were changed and updated several times during the course had many visitors. Some pages were explored for a long time, especially pages with a lot of information and pages that had to be printed, eg *Laboratory exercise*.

Netscape Navigator 2.0, the browser used by the students, did not display the Greek letters that we used in the assignments. This illustrates a problem in producing web pages. It is necessary to make them as simple as possible so that they can be displayed on the least advanced browser used. Another reason for making the web pages as simple as possible is the time it takes to download, display and print a page with a substantial amount of pictures.

By using web pages, it is possible to reach students not attending the university regularly. For those students the web pages gave an additional service that was much appreciated. By putting all or part of the information only on the web, students are forced to use computers. In the course described in this paper, the students had to work with computers anyway and the web pages became a natural tool. For courses with very little or no computer use, however, students will probably only experience the information on the web as a trendy but useless thing that only causes them extra trouble.

General information

No information or descriptions of the laboratory exercises were distributed on paper. One disadvantage that readily appeared was that printing in the students' computer rooms was extremely slow. One printer served eight to twelve computers. It took them more than 30 minutes each to print the description of the laboratory exercise. This was partly because we had included illustrative pictures. If the student should print anything at all, it is important to check in advance whether the printing can be done in a reasonable time. Otherwise, it should be short and with simple pictures.

Seminars

Web statistics (Figure 1) showed that a lot of the students visited the seminar pages, but not to the extent that we had hoped. Attendance at the seminars was good, and the students probably felt that they did not need to go through the material a second time.

The transparencies available in electronic format were easily converted to web pages. However, transparencies only available as hard copies had to be scanned, edited and presented on the web. This was very time-consuming and it was abandoned for the last two seminars.

Assignments

Adapting the assignments to the web could be considered as successful. The students seemed to use the computer as a tool in their learning and no major disadvantage was experienced.

The concept with assignments on the web had advantages both for the students and for the assisting teachers. By having all information available on the web, it was possible for the students to work more independently with the assignments. In previous years the students usually did not start an assignment before the two-hour lesson and a short introduction. Now most of the students started on their own before the lesson and many students did not show up for the lesson unless they had difficulties. The exercises could then concentrate on discussions and supporting the students through the complicated parts of the assignments.

Almost every part of the information concerning the assignments that was presented on the web was necessary. If any part had been omitted, the concept might not have been as successful as it turned out to be. The helpful hints were particularly appreciated; they made the students avoid some of the pitfalls and gave a general idea of how to solve the assignment. By having the answers on the web, the students could easily check their results to see if they had arrived at the correct solution. However, information about the approval or refusal of an assignment was considered as superfluous, as the students got this information anyway when they picked up their evaluated assignment.

From students' answers in the discussion parts, it was obvious that there is a variety of understandings about a particular phenomenon. It has been very interesting to see, through discussion with students, how learning takes place among them when they are moving from one level of understanding to a deeper level.

The concept also introduced some administrative advantages. The use of downloaded files made the students use the same variable names, making it easier for the assisting teachers to evaluate the assignments. Presenting the answers in HTML format made it possible to include graphs and larger amounts of data than easily manageable in paper format.

News

The web page with information of changes in the course was well received by the students. This kind of page is very important when the web information is

growing. It is not possible to demand that students should scan through all information in order to find additions and updates. Surprisingly, the news page did not show up to be among the most frequently requested pages. The page was probably only found by a minority of the students, but very appreciated by them.

CONCLUSIONS

Nearly all students are very positive about the change in their use of computers. Once the web pages have been produced, it is convenient to make changes. The course information can easily be changed, distributed and assessed/read by the students. The students seemed to use the web pages as expected to find information.

The newly developed assignments have changed some aspects of our teaching. One important change is that they have given students access to teaching material for undertaking their own analysis. The students are asked to formulate their own experience and judgements about the crucial content of various topics of the course. It is also important to note that students' learning achievement is followed and that the new activities are integrated with the rest of the course. All these assignments have a natural place in the course and their role is clear to the students. It is believed that the new assignments have given both the teachers and students excellent opportunities for discussion of the central topics in the course, shifting from a teaching focus to a learning focus. This project has demonstrated one possible way in which teachers can assist students to develop their own modes of understanding. It also provides a good measure of how the students approach the subject. The results are very promising and for the next course further evaluation of this project will be performed. The outcomes of the project are also expected to help us better understand how students learn and how they can be encouraged to learn in more efficient ways.

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BIOGRAPHY

Said Irandoust is a professor in the field of chemical reaction engineering, Chalmers University of Technology, Göteborg , Sweden. Said holds a Master's degree in chemical engineering (1984) and a PhD in chemical reaction engineering (1989). Since 1998 he has been a professor in chemical reaction engineering with research interest in heterogeneous catalysis and chemical reactors, specially emphasising monolithic reactors. He has been lecturing since 1989 in several courses at Chalmers and other universities in Sweden and also recently in Indonesia. Said has received a number of pedagogical awards from students and the University. He is the author and co-author of about thirty research papers within chemical engineering and engineering education. Said is also an active member of the pedagogical network at Chalmers, being involved in a number of pedagogical projects. He works part-time in the Centre for Educational Development at Chalmers

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