HYPER-TVT: DEVELOPMENT AND IMPLEMENTATION OF AN INTERACTIVE LEARNING ENVIRONMENT

MARINA SANTORO AND MARCO MAZZOTTI
ETH Swiss Federal Institute of Technology Zurich • CH-8092 Zurich, Switzerland

Rapid advances in information technology and easy access to the Web have motivated students and educators to use more and more Internet and multimedia technology for educational purposes. Educators and students are challenged by the great potential of the Internet for delivering and sharing a large amount of information among a greater public, and by the possibility of creating alternative and breakthrough ways of teaching and learning by using advanced software. Today, in almost every field of education, a broad range of e-learning material is available online. "Computer-based learning system" has been the catch phrase for the last few years to indicate a wide area of systems using the Web and multimedia technology for education.

These systems can be classified depending on the main functionality and research focus as: computer-aided education systems; multimedia/virtual laboratory; distance-learning systems; or intelligent tutoring systems.[1] This classification identifies different levels of e-education: from the simple integration of computer technologies into the traditional teaching system—where face-to-face meetings and personal relationships are still of primary importance—to the stage where the information transfer rate is no longer managed by a human tutor but it is adaptively controlled by an intelligent computer system.[1] In all cases the objective is always to use the technology not just for technology's sake, but to enhance the quality of higher education. This contribution aims to present Hyper-TVT, a public interactive learning environment on separation process technology (<www.hyper-tvt.ethz.ch>). The name Hyper-TVT derives from the word "Hypertext" and the German acronym of the course name, *i.e.*, "Thermische VerfahrensTechnik," meaning thermal separation processes.

MOTIVATION

In recent years, the educational concept has been extended toward the integration of new generations of Internet- and computer-based courses intended to lower the gap between theoretical knowledge and practical experience in the modern curriculum for process and chemical engineering. This concept addresses the nowadays frequent request of students for continuous, adequate preparation (*i.e.*, solving practical

***Marina Santoro** is a chemical engineer at the ETH Swiss Federal Institute of Technology Zurich, in Switzerland, specializing in separation process technology, with particular emphasis on the development of the new learning technologies and of e-learning tools. She has developed the e-learning system for chemical engineers, Hyper-TVT.*

***Marco Mazzotti** is professor of process engineering at ETH Swiss Federal Institute of Technology Zurich, in Switzerland. He received his B.ChE. and his Ph.D. from Politecnico di Milano, in Italy. He teaches unit operations and mathematical methods and has published more than 100 scientific papers on separation processes.*

problems and facing real issues), thus allowing them to become better aware of the physical reality of the processes, the industrial world, and their future profession. Likewise, Lewin, *et al.*, claimed that the "instruction of chemical engineers should reflect the challenges they face in industry."[2] Indeed, teaching and learning in the field of chemical engineering can be enormously enhanced by the use of information technology and Web tools. In comparison to traditional textbooks, these new avenues can offer videos, animations, and interactivity that help students visualize the reality behind equations and diagrams, thus compensating for the lack of practical experience in common engineering curricula.

In that respect, a very good reference for an e-learning environment is, in our opinion, the one developed by Fogler and Gulmer in the field of chemical reaction engineering.[3] The Web site is offered by the University of Michigan and is freely accessible online. Besides texts, equations, and diagrams, this Web site provides interactive tools for self-assessment, videos, and audio descriptions to demonstrate the concepts of chemical engineering, helping users visualize the applications within the industrial world.

In the field of separation process technology as well, all top-ranking technical universities provide e-learning systems and online courses in an effort to extend traditional chemical engineering classes. Access to these modules, however, is very often restricted to enrolled students of the course or to faculty,[4, 5] and a lot of material is available only in closed environment via CD-ROM or password-protected LAN.[6] In other cases, the courses are freely accessible but a lot of the online material provides only course information and assignments,[7] or provides the course syllabus as pdf files or PowerPoint presentations. Although this static material is of high quality and has the benefit of being always available online, a very low degree of interactivity, or none at all, is offered and therefore this approach exhibits only minor advantages as compared to traditional textbooks.

A lot of interesting material covers only some specific topic of the separation processes, such as distillation. Comprehensive theory, pictures, schemes, diagrams, and videos are published online by research groups at universities and companies working in the field.[8-11] Finally, other universities and organizations are active in the e-learning field, providing databases and links to facilitate searches for material, organizations, communities, journals, and publications about e-learning technology, such as ChemEngInfo,[12] World Lecture Hall,[13] EuPaCE.net,[14] and MERLOT.[15]

The class on separation process technology is compulsory in most curricula in process and chemical engineering. It demonstrates the application of chemical engineering principles within an industrial context for effective design of processes, particularly of multistage separation processes. Topics covered are: fundamentals of separation processes; absorption and stripping; flash evaporation; distillation; and liquid-liquid extraction. These subjects are particularly suited for the development of e-learning tools due to the synergy between theoretical issues and practical experience. Hyper-TVT is a freely accessible e-learning system for students of chemical and process engineering at the ETH Swiss Federal Institute of Technology Zurich, and also for all individuals and institutions involved or interested in process and chemical engineering education and practice. Its purpose is to complement the already existing tools, and, at the same time, to compensate for their limitations in access and scope, and to take full advantage of interactive and multimedia technology. Therefore Hyper-TVT is not comparable to commercial process simulators such as HYSYS.plant, CHEMCAD, or Aspen Plus, which have different scopes and purposes.

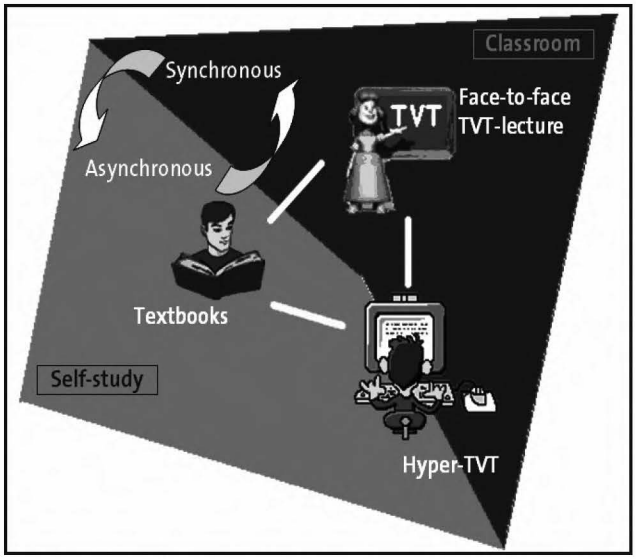

Figure 1. *Illustration of the role of Hyper-TVT with respect to traditional education methods.*

Hyper-TVT is a didactic support, which is complementary to, but not a replacement for, traditional lectures and textbooks. In fact, combining Hyper-TVT with conventional education elements—*e.g.*, lecture, textbook study, and discussion with the teacher—contributes to enhancing teaching effectiveness and flexibility. The Web site offers both educators and students a number of tools such as videos, animations, simulations, and a self-assessment environment, thus creating a better balance between synchronous and asynchronous approaches in teaching and learning, as illustrated in Figure 1. The design concepts, the didactic content, and the technical features of Hyper-TVT will be discussed in detail in the following chapters.

DESIGN CONCEPT

"Textbook" structure

The structure of the Web site is organized in chapters and paragraphs, as it would be for a traditional textbook. Figure 2 is a screenshot of the page content of the "Contactors"

lesson as an example of page structure. The choice of minimizing any structural complexity has two purposes: to let students and educators focus better on the Web site content, and to make using the tool as easy as possible. Within each paragraph the topic is presented using explanatory text, images, and interactive diagrams and schemes. Every paragraph develops a certain concept independently and completely by integrating the multimedia material within the text and by providing logical links to other pages of the learning environment.

Navigability

Due to its simple structure and the implementation of a navigation system, the Hyper-TVT Web site is easy to browse. In every section of the Web site, menus help answer three fundamental questions[16]: Where am I?; Where have I been?; Where can I go? Within every lesson, an interactive table of contents highlights the user's current location within the lesson, helps to find other related content, and suggests the logical learning sequence, as shown in Figure 3.

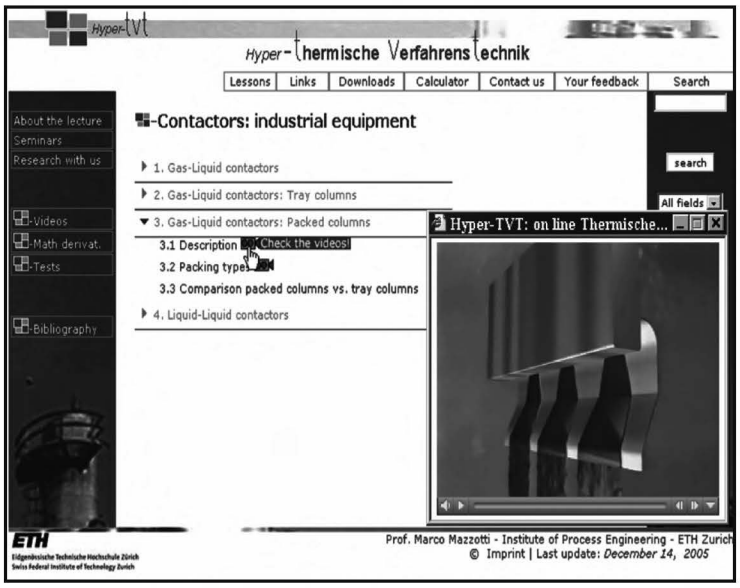

Figure 2. *Structure of the "Contactors" lesson with chapters and paragraphs. A screenshot of a video on column internals is shown on the bottom right.*

Interactivity

The added value of a Web-based educational system is the interactivity offered to students and educators. The Hyper-TVT system stimulates interactivity through pictures, animations, a modeling and simulation environment, videos, and self-assessment tools, all of which are very consistent with the learning objectives in the domain of process and chemi-

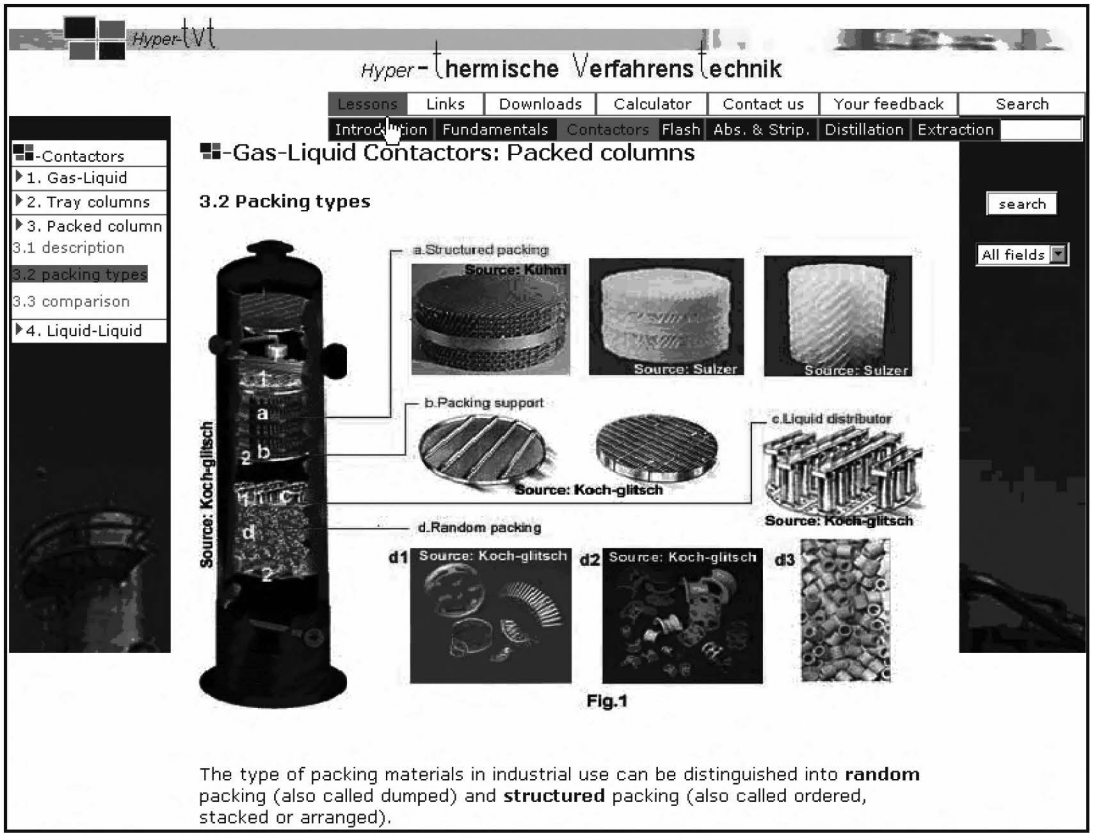

Figure 3. *Packing types in the "Contactors" lesson. On screen the path is indicated by orange-highlighted items in the menus.*

cal engineering. Two examples of animations about distillation topics are shown in Figure 4.

Reusability

Hyper-TVT teaches some of the key separation processes technologies, *i.e.*, a fundamental subject in the process and chemical engineering curriculum that is well established. For this reason, the content of Hyper-TVT is not expected to be subjected to revision in the near future, if ever.

Therefore the Hyper-TVT Web site is available, now and in the future, to students, educators, and practitioners of different institutions, countries, and educational sectors, *e.g.*, higher education, vocational training, professional organizations, industry, and schools.

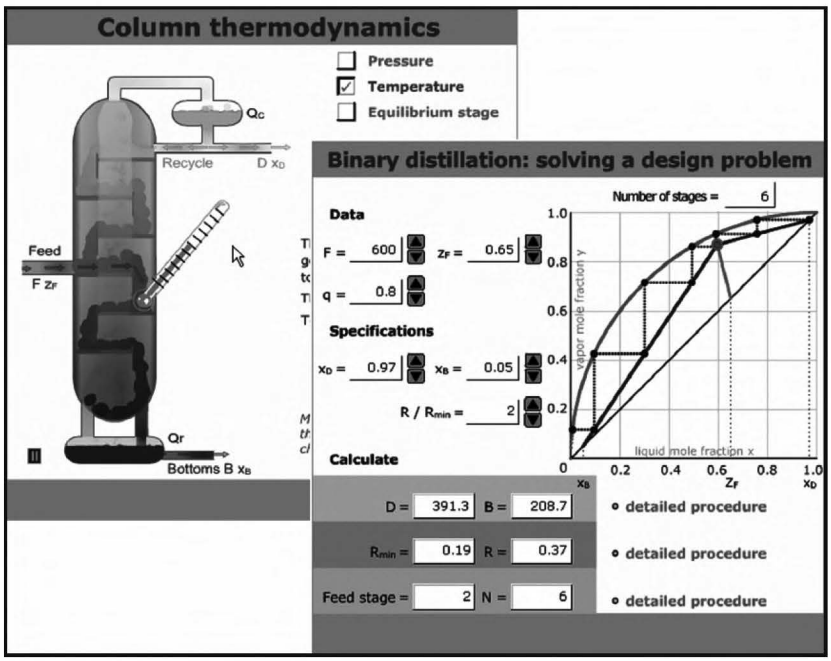

Figure 4. *Interactive Flash animations within the "Distillation" lesson.*

Outreach to other categories of users

The target users of Hyper-TVT consist of all individuals and institutions involved in process and chemical engineering education. Its simple structure, links, and interactive modules, however, make Hyper-TVT easy to be followed by others, who, though not chemical or process engineers, still need or want a quick and complete overview of the separation process technologies.

DIDACTIC CONTENT AND METHOD

Hyper-TVT consists of seven lessons presenting class material using text, images, animations, interactive tools, and simulation environments. These are:

1. *Introduction of separation processes*
2. *Fundamentals of separation processes*
3. *Contactors*
4. *Absorption and stripping*
5. *Flash evaporation*
6. *Distillation*
7. *Liquid-liquid extraction*

The first lesson is a presentation of the separation processes and their role and importance in the industrial context. In the second lesson, basics of thermodynamics and mass transfer are revisited; these are fundamental for further understanding of multistage separation technologies. Lesson number three, on contactors, presents an overview of the industrial equipment for gas-liquid and liquid-liquid separation. Lessons four, six, and seven cover the design of three of the most important multistage separation processes. The fifth lesson, on Flash evaporation, introduces many concepts useful to understanding distillation. The didactic approach first provides students with all basic concepts and tools needed. Then, students are challenged to use the new material to solve problems given as home assignments. Besides the lessons, three additional sections of the Web site contain videos that can be streamed, PowerPoint and pdf files that can be browsed, and tests that can be used for self-assessment. The videos focus on industrial equipment for separation processes (*i.e.*, lesson three) and have been partly created for this use and partly provided by companies, *e.g.*, Sulzer ChemTech, Kühni, and FRI (Fractionation Research, Inc.). In the videos, an off-screen narrator guides the visitor into a virtual tour of the real equipment to observe directly and in detail phenomena that neither words nor photos alone would be able to clarify. A screenshot of a video about column internals is shown in Figure 2. Videos can have a great didactic value, and not just in the field of chemical and process engineering, because they overcome physical barriers and bring the world into the classroom. The PowerPoint and pdf files are a collection of mathematical derivations of the equations used in the lessons for process design. Their format allows students to use them interactively online or to download them for further reading. The test section provides multiple choice and descriptive questions. Students also have the option to submit completed questionnaires, receive support online, and access and print homework assignments as pdf files. Another important element of the Hyper-TVT Web site is its database. The database contains five specific search categories, *e.g.*, text, notation, images, glossary, and bibliography. The "text" category provides links to pages where keywords are mentioned. "Notation" contains detailed explanation of all the symbols used in the Hyper-TVT Web site. "Images" is a collection of diagrams and graphics already present in the lessons, but it

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also contains additional pictures, schemes, and photos of real equipment provided by various companies. The "glossary" category is a compact dictionary of terms specific to the lessons presented in Hyper-TVT. Finally, the "bibliography" provides a list of suggested textbooks, handbooks, and further readings. All five categories can be accessed by a search tool. This allows visitors and students to make quick searches in a specific area of interest and find direct links to the Web site's relevant section.

A further aspect of the Web site is its toolbar. This provides three additional links: to some of the most important chemical engineering companies in the field of the separation process technology; to the required-plug-ins Web page; and to an evaluation section for online feedback and comments.

TECHNICAL FEATURES

Hyper-TVT is an independent learning environment in which technical tools and software have been chosen not only to suit the pedagogic needs of the class on separation processes but also to facilitate its future management, maintenance, and upgrade. Access is also possible from limited-band connections, and compatibility has been guaranteed for all main browsers on both PC and Mac machines. The architecture of the Web site is based on the PHP scripting language, which allows for creation of dynamic pages and the use of databases, particularly of MySQL. Javascript has been used to build the navigation menus and the interactive tools, *i.e.*, the table of contents and the self-assessment environment. Animated diagrams, schemes, and interactive presentations have been shown with Flash, Real Player, and QuickTime. Each has also been used for video streaming. Finally, MathML (version 1.0), has been used to edit and display the mathematical equations. At ETH Zurich, Hyper-TVT has been one of the first educational projects to use MathML, thus providing a useful and successful experience for other projects as well.

DISCUSSION AND CONCLUSION

The development of Hyper-TVT started in July 2001 and its realization has taken three-and-a-half years with one person working on it full time. A prototype of the Web site was released to students in June 2002, and their feedback has been used during revision of the site and completion of the project. The whole environment is continuously revised based on feedback collected in different ways. The ETH students attending the class are asked to fill out an evaluation form at the end of the semester, and an online evaluation form allows students and educators from other institutions to provide helpful comments. On one hand, these have been used for modifications, refinements, and improvements of some parts of the Web site. On the other hand, and more in general, feedback from ETH Zurich students indicates 95% appreciated the learning environment and found it useful, both during lectures and outside the classroom, as support material and in completing homework assignments. The Web site is used very intensively in preparation for the final exam. The major advantage, as indicated by students, is the interactive and audio-visual content, *i.e.*, the flash animations, videos, diagrams, and pictures. As a further positive comment, students and practitioners underline the easy navigability offered by the Web site. Very positive reactions have been received from educators of other institutions and technical universities as well. The result, although possibly not yet statistically relevant, is very encouraging about the usefulness of the Web site.

Use of the Web site is not a requirement of the separation processes class for students at ETH Zurich. Rather, the Web site is presented at the beginning of class as additional support and its interactive material and videos are used during some of the lectures. In this way, students get a first impression of the real world of separation process technology while gaining familiarity with the Web site, thus making its use easier. The purpose of this approach is to increase student interest about the proposed subject with more motivating material and tools, thus stimulating their self-study skills and responsibility.

The most difficult issue we have experienced as instructors has been integration of the Web site during traditional lectures. In fact, this implies an allotment of time in the lecture plan for use of the computer-based didactic material. This is not a simple task since the traditional course has to be reorganized and restructured to implement a new hybrid methodology (traditional and computer-based lecture). It requires an additional effort and a lot of motivation by the instructor. For students as well the integration of the Web site into their traditional way of learning is challenging. Many studies have been conducted to determine what factors impact the perception and acceptance of new e-learning tools on students.[17] Such tools generally require students to become more independent and

more responsible of their personal learning processes, and to apply new technologies—an additional workload that is not always well received at first. With the time and guided assistance of the tutor, however, students usually recognize and appreciate the benefits of the computer-integrated educational system. Typically, their learning efficiency and performance improve, resulting in increased self-confidence and greater motivation.

The Hyper-TVT system is available online (<www.hyper-tvt.ethz.ch>) and can be accessed without restrictions through the Web.

Hyper-TVT shows how dissimilar pedagogic methods—traditional and Web-based—can be implemented in parallel to offer a more stimulating and productive learning environment. Students, in turn, gain tools for self-paced learning and become more autonomous. Use of Hyper-TVT can foster their skills in analysis, synthesis, and evaluation. Finally, the lecture time with the instructor can be invested more effectively to discuss advanced issues. Our experience in using Hyper-TVT has been very positive so far, and we encourage students, educators, and chemical and process engineers to explore it as well.

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