Using a Web Platform Developed for the Teaching of Chemical Processes to Reach Secondary School Students

http://dx.doi.org/10.3991/ijoe.v8iS2.1982

M. G. Rasteiro, M. G. Carvalho, A. Ferreira, C. B. Gaudêncio and J. Granjo
University of Coimbra, Coimbra, Portugal

***Abstract*—As a complement to the teaching of university students, the use of web based tools enhances students' autonomy, helps in dealing with different learning rhythms and allows reaching students in different locations. Moreover, the web can also be used to attract youngsters (basic and secondary school students) to science subjects. All these functions have been combined in a single web platform "LABVIRTUAL", based in the Chemical Engineering Department of the University of Coimbra. Even if the Portal was developed for the Teaching of Chemical Processes, a specific section directed to the secondary school students has been created as well, grounded on the basic concepts they acquire at the secondary level. In addition, the portal possesses an area dedicated to the understanding of Chemical Engineering. By guiding the secondary school students to the use of these tools, they are led to understand the connection between Engineering (Chemical Engineering) and the basic phenomena they are studying. Moreover, the proximity factor can contribute to rouse the curiosity of the users to search for more advanced information about Chemical Engineering science and applications. This approach may motivate them to engineering subjects and also to raise their interest in the study of basic science subjects for which they start finding a practical application.**

***Index Terms*—Chemical processes, secondary schools, simulators, web tools**

I. INTRODUCTION

The use of web based tools as a complement to the teaching of university students is becoming quite popular at university level. In fact, it is believed that these tools can enhance students' autonomy and help in dealing with different learning rhythms. Moreover, these tools allow reaching students in different locations. These facts have been acting as a driving-force to motivate engineering educators to develop new teaching methodologies [1-5].

The Chemical Engineering Departments of both the Universities of Coimbra and Porto, in Portugal, developed an integrated platform to teach Chemical Processes, which possesses unique features (http://labvirtual.eq.uc.pt). This portal addresses the main areas of Chemical Engineering: Process Separations, Reaction Engineering and Process Systems Engineering, and also Biological Processes (reaction and separation). In each of these areas the Portal is organized in three sections: fundaments; simulation modules; case studies [6]. In addition, there is a section called "Virtual Experiments", which interacts with the domains mentioned above, and where the students have access to videos of experiments running in the laboratory, which illustrate the concepts developed in the fundaments pages. Moreover, there is also a section with remote control experiments. Through this strategy the student can integrate more easily theory and simulation knowledge with the visualization of the phenomena occurring in the laboratory. Figure 1 presents a scheme of the platform.

Another well known current practice, is to use web applications to attract youngsters (basic and secondary school students) to science subjects. Even if this is not yet so common in the engineering field, some universities have been following this strategy, as for instance the John Hopkins University in USA (http://www.jhu.edu/virtlab/index.html), the Oregon State University [7], and, more recently, the American Institute of Chemical Engineers, AIChE, developed a special section devoted to these matters ("Dream up the Future" - http://egfi-k12.org/). Also worth mentioning is the web site "Discovering Engineering - http://www.discoverengineering.org/, sponsored by several major engineering companies.

In the aforementioned project we have chosen to combine in a single web platform the two functions described above. Thus, we have decided that the portal for the teaching of Chemical Processes could be used as well to reach the secondary school students. With one single portal we will then be reaching simultaneously two different publics: Chemical Engineering students and Secondary School students. For that, we have created, in the portal, a specific section directed to the secondary school students. Moreover, the portal possesses an area, directly connected to the home page, dedicated to the understanding of Chemical Engineering. In that area we address such fields as: What is Chemical Engineering about; the History of Chemical Engineering; a summary of Education and Research in Chemical Engineering around the world and information on which are the novel areas of Chemical Engineering (Biosystems, Energy and Environment and Nanotechnologies). Besides these public awareness fields, in the Secondary School Students zone we have developed contents, both in the field of Physics and Chemistry, that take into account the subjects taught at the secondary school level. For that, we have taken advantage of some applications prepared for the engineering students, which were adapted for this other public, and which can then be used by the secondary level students as for instance in the fields of Heat Transfer, Reaction Kinetics, Thermodynamics and Distillation. In the section specifically dedicated to the secondary school students we try to establish a link between basic science concepts (physics and chemistry)

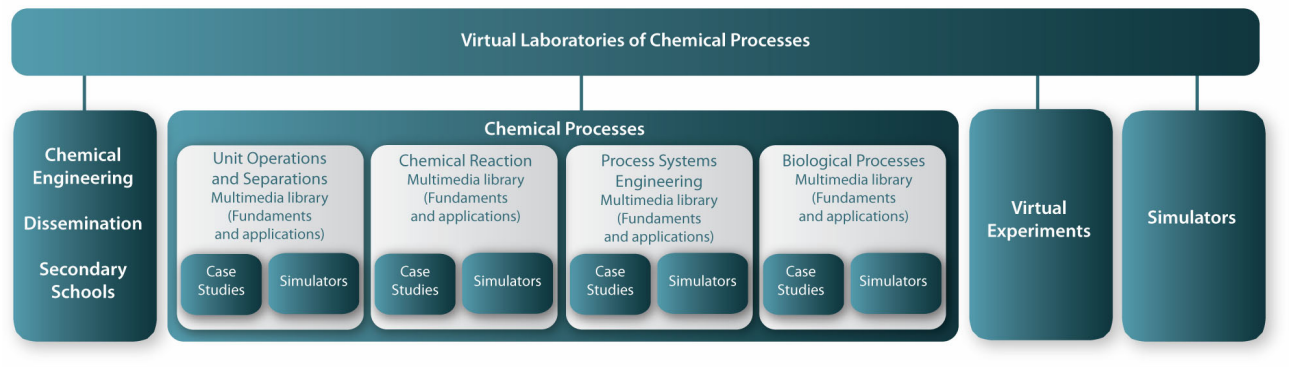

Figure 1. Scheme of the platform.

and Chemical Engineering applications, taking into account the level of knowledge corresponding to that school stage.

By guiding the secondary level students to the use of these tools, which are based on the basic concepts they acquire at the secondary level, they are led to understand the connection between Engineering (Chemical Engineering) and the basic phenomena they have been studying. This way, they start to understand how engineering works and how basic scientific knowledge is related to the products of engineering that surround us.

Moreover, since this platform is intended to be a dynamic Web Portal open to share experiences with other schools and educators, in the future it is intended to organize a discussion forum, available through the home page, to interact with the secondary school teachers.

In this paper we will present a description of the contents of the section, included in the LABVIRTUAL Platform and directed to the secondary level students, which we have named "Secondary Schools", and of the strategy we have been using for the dissemination of this feature of the portal to that public. Moreover, we will give notice of the results of the survey launched among the 1st year Chemical Engineering students at the University of Coimbra, who registered for the school year 2010/11, where we have asked them if they had been previously aware of the platform LABVIRTUAL and, if so, which was their evaluation of the portal.

II. DESCRIPTION OF THE SECTION "SECONDARY SCHOOLS"

The section "Secondary Schools" can be accessed directly from the portal home page. Furthermore, when entering the home page the user faces several other sections which are aimed at disseminating information about Chemical Engineering, organized according to the scheme in Figure 2.

The main objective is to inform the user, namely secondary level students, about what Chemical Engineering is about, the history of Chemical Engineering, in which sectors do chemical engineers work, which are the new trends in Chemical Engineering (with information about the application of Chemical Engineering Science in fields which are not usually associated by the general public to Chemical Engineering, such as: nanotechnologies, biosystems, including applications in medicine and health care and also environment and energy). Additionally, the user can also find information in the home page about trends in education in Chemical Engineering, including a list of renowned institutions/universities all over the world (with links to their web pages).

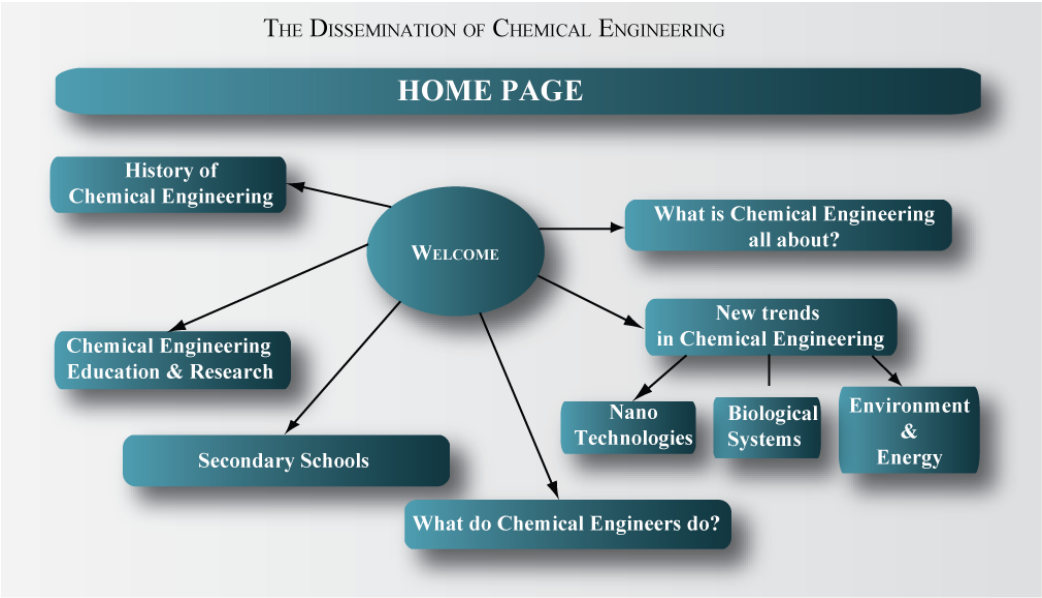

Figure 2. Scheme of the sections directed to the dissemination of Chemical Engineering.

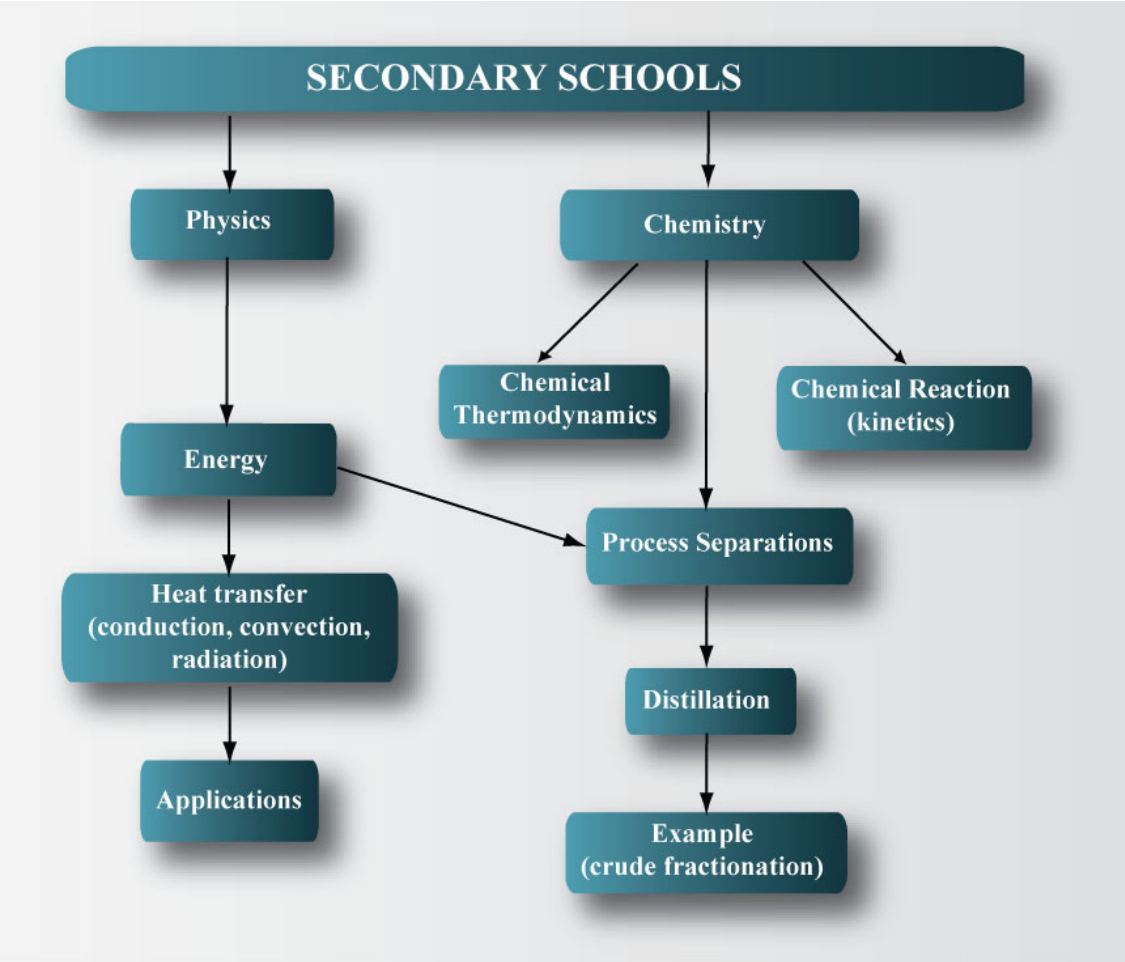

Figure 3. Scheme of the Secondary Schools section.

It is through the home page that all the sections in the portal can be accessed, namely the sections directed to chemical engineering students (Chemical processes, Virtual Laboratories and Simulators) as well as the section "Secondary Schools". In order to access the virtual experiments and the simulators the visitor is required to pre-register as a user of the portal. This pre-requisite aims at identifying the users which reveal a deeper interest in Chemical Engineering. Nevertheless, registration is not restricted to chemical engineering students from the universities that were involved in the development of the project and is also available to secondary school students and teachers.

The section "Secondary Schools" has been constructed in order to lead the users to understand how basic sciences (Chemistry and Physics) are the foundation of engineering applications that surround us everyday, namely the ones that are developed by chemical engineers. The main objective is to motivate the students to engineering subjects, showing them that engineering is based on the basic subjects that they are learning at secondary education: chemistry, physics and also biology. Moreover, this section aims at explaining the user that engineering turns basic sciences into practical applications that can make human life easier, healthier, help in feeding the world population, etc. Thus, the Secondary Schools section is organized in two main areas: Physics and Chemistry. Figure 3 shows, in a schematic way, the different fields in the "Secondary Schools" section.

The Physics section covers the basic principles of thermodynamics and heat transfer where the relevant concepts are gradually introduced, including thermodynamic laws. The section starts with a brief history of Science and the genesis of Physics. The meaning of Heat and Work as energy transfer between a "system" and the surroundings is explained. What is energy, how many forms of energy have been defined and how energy can be converted from one form into another are topics also addressed. Several sources of energy are also illustrated and divided into renewable and non-renewable. Examples are intended to show how heat transfer mechanisms are used in real-world situations, as seen in Figure 4. The principle of energy conservation is postulated and applied either to close or open systems. Some experiences like water heating calculation in an electric teapot with a known heating power, followed by water loss estimation during a fixed boiling time are described, which can be repeated at home. The causes and the mechanisms of these heat transfer processes are discussed. This example clarifies the concepts and illustrates the use of basic principles such as the energy balance, energy source, energy conversion, sensible energy, latent energy, heat transfer, heat transfer rate and transient and steady states. Since heat transfer plays a crucial role in the design of many household and industrial appliances, the users are made aware of its importance on everyday life with emphasis on understanding the physical mechanisms.

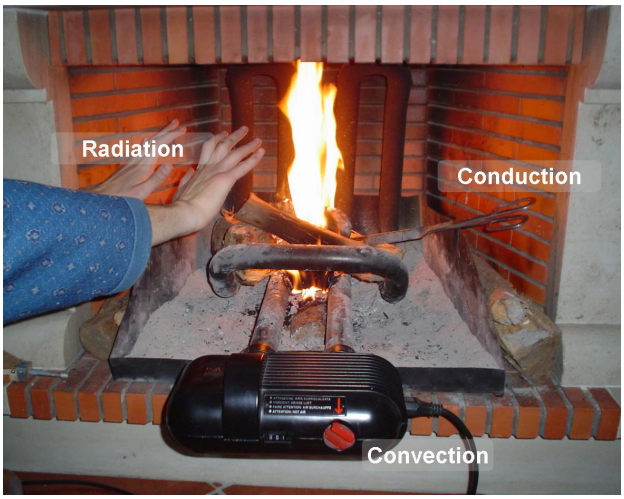

Figure 4. Heat transfer mechanisms: thermal radiation in the hands, conduction in the pincers and convection to the air flowing inside the tube of the heat recovery ventilator.

The Chemistry sector is divided in three subsections: Chemical Thermodynamics, Process Separations and Chemical Reaction. Figure 5 presents an image of the entrance page to the Chemistry section.

The Chemical Thermodynamics page deals with the basic concepts of vapor/liquid equilibrium. In this section there is also information and an animation on how to measure vapor pressures. The other section under the topic of Chemical Thermodynamics is the vapor/liquid equilibrium of mixtures. The discussion is based on the hypothesis of ideal system, thermodynamic models for this situation being presented. The user is led to understand how to build a boiling point diagram for a binary mixture, or to look at a molecular animation of the simulation of vapor/liquid equilibrium of mixtures (http://labvirtual.eq.uc.pt/siteJoomla/index.php?option=com_content&task=view&id=217&Itemid=382). The Chemical Thermodynamics section supplies the background for the understanding of the Distillation case study under the topic of Process Separations.

In the Process Separations section the user can get information on applications of process separations in everyday life and at the industrial level. Only Distillation is developed in detail in the Process Separations page of the "Secondary Schools" section. In this page the student is faced with information on the principal mechanisms behind the distillation process and on how to conduct it at lab scale. Some preliminary information on the design of distillation equipment including information about the different components in a distillation column is also supplied. Additionally, the section includes also a case study dealing with the distillation of crude oil. The student can start by finding information on crude composition, on how it varies from place to place, on crude oil processing and also about the different products that can be obtained from crude refining. The concept of octane index and its relation to the different hydrocarbons structure is also discussed.

After this introduction, the student has got access, in the distillation case study page, to a simple distillation simulator prepared to simulate the separation by distillation of a simple mixture of hydrocarbons (linear and cyclic) which we named a "simulated crude oil". The simulator gives as an output the design of the distillation column (number of stages, heat supplied in the reboiler, products composition and profiles (temperature and composition) along the column). By running the simulator the student is then led to understand how the vapor and liquid compositions vary along the column, with the more volatile components being collected in the distillate and the less volatile in the bottom product. Furthermore, by trying different operating conditions for the simulation the student can also understand how operating variables, such as pressure or reflux ratio, influence the column dimensions (height and diameter), or still their influence on the energy required by the process or on the purity of the products obtained. The input data form contains data introduced by default which can be altered by the user. Figure 6 shows one of the outputs of the distillation simulator: a schematic description of the distillation column with indication of the results obtained.

Some information is also supplied about other types of fuels and it is suggested that the user applies the simulator also to the purification of bioethanol. Moreover, in the Process Separations section the user is motivated to access other links related to the subject and also to explore other more advanced sections of the portal in the same field, which were originally developed for Chemical Engineering students.

The last section of the Chemistry sector deals with Chemical Reactions which are introduced as processes enabling to obtain new molecules and therefore new products, while using other molecules as reagents. Emphasis is given on how important this field is to enable producing and developing the products that ensure our daily needs, from food to transportation, not forgetting medical care or the materials for nowadays communication technologies. Different types of reactions are introduced, in order to show that particular conditions and systems are required for molecules to react. Moreover, the rate of these reactions can be manipulated in order to increase the production of the required products. A second part of this section deals with chemical reaction kinetics and how operating conditions, such as chemical composition and temperature, can influence it. The general reaction rate equation is presented and different forms for the concentration dependent term are given, while alerting that experimental data are required to confirm the reaction rate equation. It is also enlightened how temperature affects the rate of reaction and that the activation energy and the Arrhenius law enable understanding how sensitive the reaction is to temperature. At the end of this section students are invited to answer a short quiz to evaluate how much they have learned from the information presented.

It must be stressed that the inclusion of contents directed to Secondary Schools in a web portal constructed mainly for university students is expected to rouse the curiosity of the younger public leading them to search more advanced subjects in Chemical Engineering, thus increasing their knowledge of what Chemical Engineering is about and where it can be applied and, thereafter, raising their interest in this subject. Throughout this section of the platform the visitor can find links to other web pages and, most of all, is motivated to visit other sections of the portal that go deeper into Chemical Engineering Science.

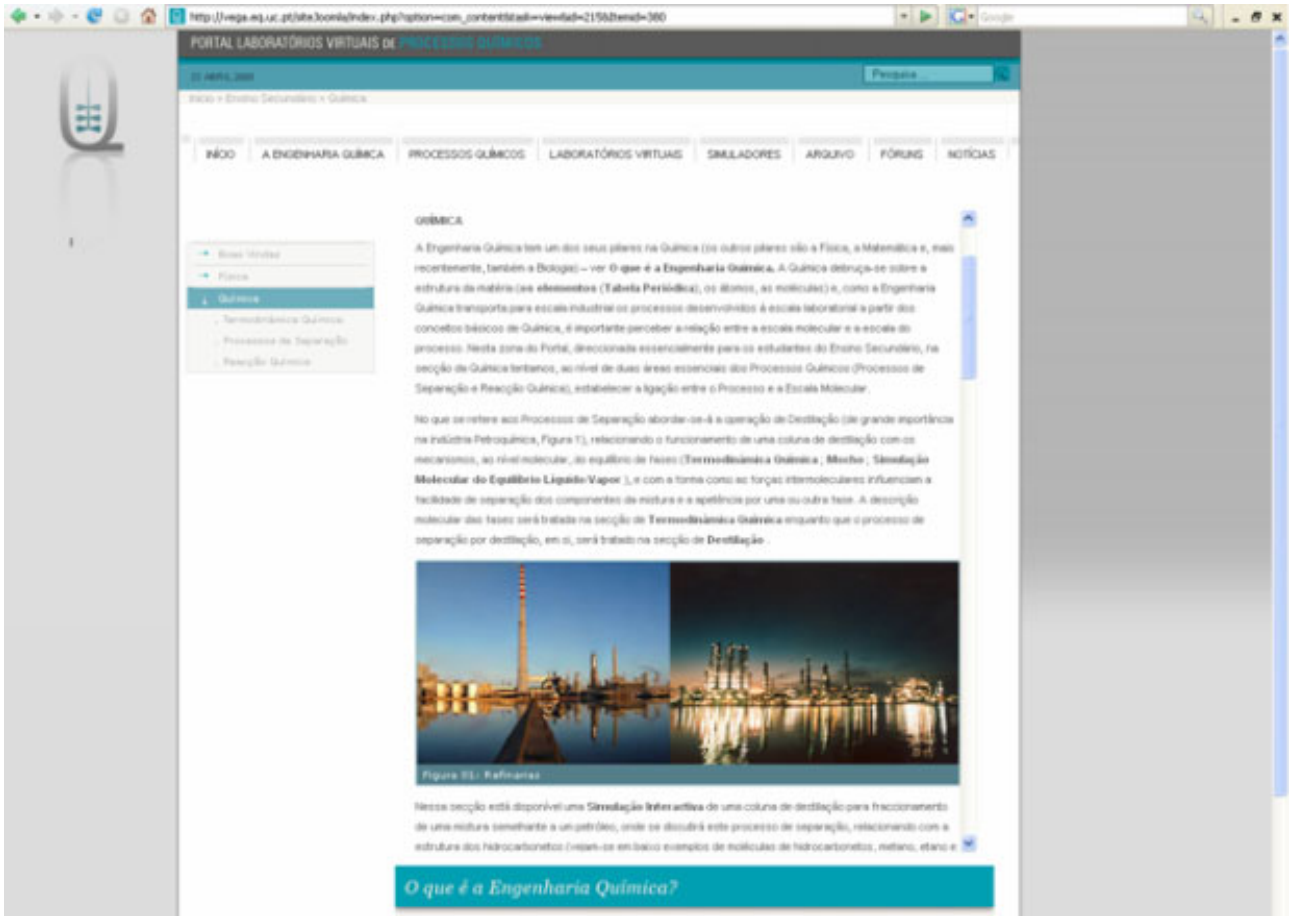

Figure 5. Chemistry entrance page (in Portuguese).

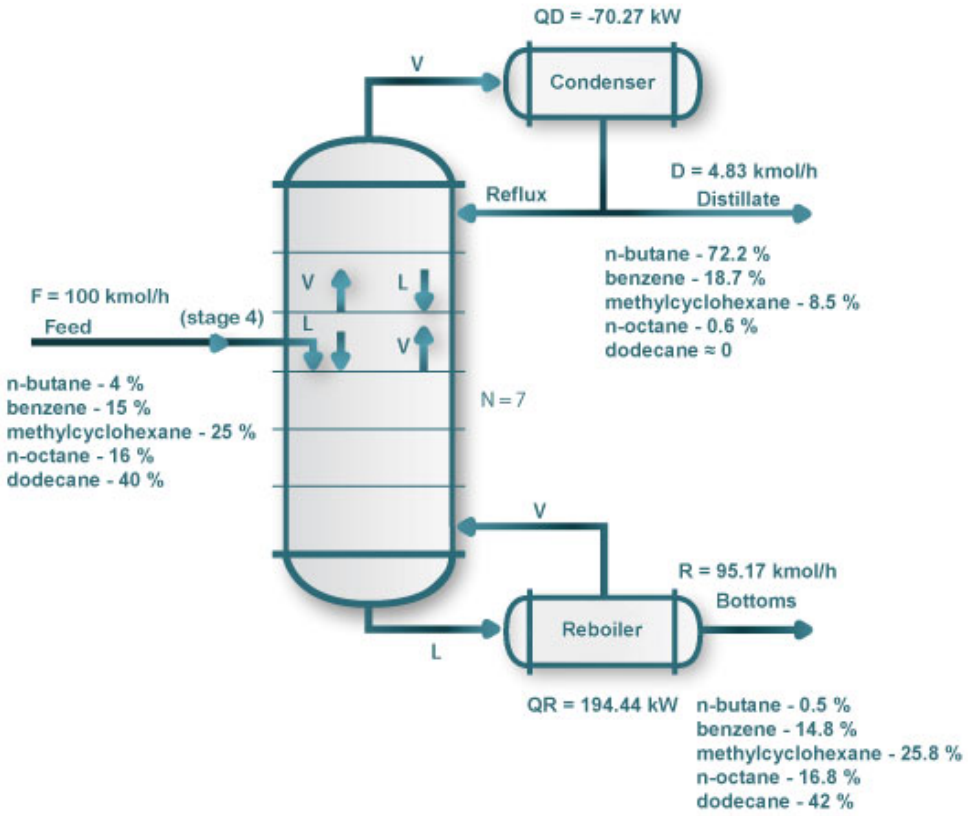

Figure 6. Output from the distillation simulator.

III. STRATEGY FOR THE DISSEMINATION OF THE PORTAL TOWARDS SECONDARY SCHOOLS

In order to disseminate information about the portal to the secondary schools (teachers and students) different actions were prepared. First of all we have prepared several "marketing" materials: a leaflet describing the main functionalities of the portal, a poster and a CD with some examples of applications included in the portal, always aiming at capturing the curiosity of the user to explore further the other applications existing in the platform.

The first action undertaken in order to catch the attention of the secondary schools public to the existence of the portal was directed to the teachers. The platform was launched to that public in 2009 in a session specially designed for the secondary school teachers. In that session, where the "marketing" material was first distributed, there were several presentations explaining the objectives and the different functionalities of the portal, mainly the ones in the "Secondary Schools" section. This introductory session with oral presentations was followed by a "hands on" session in the computing centre, tutored by several members of the team involved in the development of the project, where the teachers could try, on their own, some of the applications included in the portal. In fact, one of our goals is that the secondary level teachers make use of information, examples or applications in the portal (secondary schools section) in their own classes.

Other actions have been undertaken afterwards to make the portal known to the secondary school public: direct mailing of information about the portal to the secondary schools; distribution of information about the portal in vocational fairs aimed at secondary and basic level students; direct distribution by the University, in secondary schools, during the sessions aimed at disclosing information about the higher education offer by the University of Coimbra; open days of the Chemical Engineering Department, where the students are introduced to LABVIRTUAL. The material with information about the Labvirtual Platform is now part of the package of information the University of Coimbra makes available to the secondary schools.

The basic idea behind these different dissemination actions is to make the portal known to the secondary schools public and, by doing so, turning it effectively into a dynamic tool for the dissemination of Chemical Engineering among that public, which the students get used to seek when they think about choosing a profession.

In the school year 2010/11 we started monitoring the dissemination of LABVIRTUAL among the students registered for the 1st year of Chemical Engineering in the University of Coimbra. During their first weeks in the university they were asked to fill a questionnaire which includes some questions related to their knowledge of the portal LABVIRTUAL, such as:

- Have you had previous knowledge of the portal LABVIRTUAL?
- If so, have you used it in your school?
- How do you rate the section "Secondary Schools" of the portal LABVIRTUAL?
- Did the information you found in the portal improve your perception of Chemical Engineering?
- Did the information you found in the portal influence, somehow, your choice to register for a Chemical Engineering degree?

In this school year only 34 students, out of 50, replied to the survey. From these respondents 7 mentioned to have had previous knowledge of LABVIRTUAL while they were still at secondary school, and, most significant, five of them mentioned that the information gathered there clarified for them what is Chemical Engineering about and helped in deciding which course to choose for their university education.

Though still quite preliminary, this is considered a very positive outcome of the strategy followed by us to include a section devoted to secondary schools in a web portal directed to Chemical Engineering students.

IV. END NOTES

It is still too early to withdraw firm conclusions from the work developed, which was based on the strategy of building a section directed to the secondary school level public in a platform constructed for the teaching of Chemical Processes to university students.

It is believed that this strategy has got the advantage of increasing the probability of rousing the curiosity of the visitors from that public to more advanced subjects in the field of Chemical Engineering, which is available to them in the same portal. This proximity advantage can contribute to improve their level of knowledge about Chemical Engineering.

The registration system allows us to acquire information on the visitors of the portal possessing the added curiosity to go beyond the home page to the more advanced sections. The platform is prepared to treat that information to produce statistics about the visitors' affiliation and nationality.

That information will be of utmost importance in the future to evaluate the degree of dissemination of the portal among the public belonging to the secondary education level and, thus, the success of the portal as a tool to disseminate information about Chemical Engineering.

The questionnaire distributed to the first year students reveals that the portal is already penetrating among the pre-university students, and the results obtained indicate that this tool can be important to clarify their doubts about what is the profession of Chemical Engineer.

ACKNOWLEDGMENT

The authors want to acknowledge the receipt of a sponsorship from POSC, Portugal, contract 743/4.2/C/REG, which enabled the development of the platform described in this paper and all the team involved in the development of the project.

REFERENCES

[1] M. Kadiyala, B. Crynes, "A review of literature on effectiveness of use of information technology in education", J. Eng Ed, vol. 89 (2), pp. 177–189, 2000.

[2] S. J. Streicher, K. West, D. M. Fraser, J. M. Case, C. Linder, "Learning through simulation—student engagement", Chem Eng Ed, vol. 39 (4), pp. 288–295, 2005.

[3] T. F. Edgar, "Enhancing the undergraduate computing experience", Chem Eng Ed, vol. 40 (3), pp. 231–238, 2006.

[4] A. Klein, G. Wozny, "Web based remote experiments for chemical engineering education—the online distillation column", Trans IChemE, part D, Educ Chem Eng, vol. 1, pp. 134–138, 2006. http://dx.doi.org/10.1205/ece06015

[5] A. Selmer, M. Kraft, R. Moros, C. K. Colton, "Weblabs in chemical engineering education", Trans IChemE, part D, Educ Chem Eng, vol. 2, pp. 38–45, 2007. http://dx.doi.org/10.1205/ece06018

[6] M. G. Rasteiro, L. Ferreira, J. Teixeira, F. P. Bernardo, M. G. Carvalho, A. Ferreira, R. Q. Ferreira, F. Garcia, C. G. Baptista, N. Oliveira, M. Quina, L. Santos, P. A. Saraiva, A. Mendes, F. Magalhães, A.S. Almeida, J. Granjo, M. Ascenso, R. M. Bastos, R. Borges, "LABVIRTUAL - a Virtual Platform to Teach Chemical Processes", IChemE Transactions D - Education for Chemical Engineers, vol. 4, pp. e9–e19, 2009. http://dx.doi.org/10.1016/j.ece.2009.02.001

[7] M. Koretsky, D. Gilbuena, A. Kirsch, "Engaging high-school students in engineering, science and technology using virtual laboratories", Proc. ASEE Conf., Austin, USA, 2009.

AUTHORS

M. G. Rasteiro is Associate Professor of Chemical Engineering at the University of Coimbra, Portugal, President of the Chemical Processes Research Center from the same university, a member of the board of directors of Ordem dos Engenheiros–Centro (Portuguese Engineers Association) and leader of SPEE working Group of IT's in Engineering Education (email: mgr@eq.uc.pt).

M. G. Carvalho is Assistant Professor at the Chemical Engineering Department of the University of Coimbra, Portugal, and has been teaching Heat and Mass Transfer Fundamentals and Applications subjects over the last 25 years (email: mgc@eq.uc.pt).

A. Ferreira works currently as Associate Professor of Chemical Engineering at the University of Coimbra and is member of Ordem dos Engenheiros (Portuguese Engineers Association). His main reserach interests are centered on determination and interpretation of thermophysical properties of liquids and liquid solutions (email: abel@eq.uc.pt).

C. M.S.G. Baptista is Assistant Professor at the Chemical Engineering Department of the University of Coimbra and carries out research in Process System Engineering (email: cristina@eq.uc.pt).

J. Granjo is a PhD student of the CIEPQPF Research Center (FCT Grant: SFRH/BD/64338/2009). His research interests include biofuels production processes; industrial operations and equipment design; process systems engineering tools to support decision-making and web development tools (email: josegranjo@eq.uc.pt).

This work was supported by Calouste Gulbenkian Foundation, Lisbon, Portugal. It is an extended version of a presentation given during the 1st Experiment@ International Conference, 17/18 November 2011 in Lisbon, Portugal. Manuscript received 10 February 2012. Published as resubmitted by the authors 18 March 2012.