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TEACHING STRATEGIES AND INDUSTRIAL COOPERATION IN A PROCESS DESIGN COURSE

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ABSTRACT

The teaching strategy for a process design course at Universidad del Valle, one of the most traditional schools of Chemical Engineering in Colombia, is presented. The strategy is designed to strengthen the engineering skills, and also the so called "transferable" skills (i.e., teamwork, communication, self evaluation, and creativity) of the ChE students, and to provide studies of interest for the local industrial sector.

The class activities are designed to explore aspects related to teamwork, process synthesis, process safety, cost estimation and application of economic engineering concepts. Each class session is followed by a workshop in which the students work in teams and immediately practice the concepts previously studied. We use cooperative learning by asking each team to select one leader of process technology, one of market intelligence, and one of economic evaluation, and by offering specific workshops on these topics to the respective leaders, whom are responsible for teaching their teammates.

The subject of the design project is defined in consultation with engineers from industry, which act as external consultants for each project during the semester. The final assessment of each project is made by practicing engineers. Follow up and guidance are provided by the instructor and two graduate assistants. Each semester the projects are organized in a CD-ROM, which contains useful information, articles and patents included, such that any potential investor can easily find relevant information. Topics studied in the last few years include lactic acid, fuel alcohol, biodiesel, and several high-added-value products from industrial waste.

1. INTRODUCTION

The Process Design course is one of the most important components of a Chemical Engineering curriculum because it allows the students to connect many of the concepts they have studied during several years, and to direct them towards the plannning of a chemical processing unit. This exercise offers inmense posibilities for the development of skills such as teamwork, communication, selfevaluation, integrative thinking, and creativity, among others. In addition, the design course provides an important opportunity for cooperation with industrial partners by choosing design projects that are relevant to them and by following up the projects in the involved industries. The purpose of this paper is to present the structure and characteristics of the process design course currently offered at Universidad del Valle, which was implemented to develop in the students the above mentioned skills, and to favor a strong cooperation with the industrial sector.

2. COURSE OBJECTIVES AND STRUCTURE

The objectives has been established to reach a number of educational goals that represent a very acceptable level of competence for a recently graduated engineer. The general purpose is to qualify the student in the methodologies currently in use for preliminary chemical process design, from the selection of processing alternatives and the employment of technical and economic criteria for their evaluation, to the establishment of operating conditions that meet the requirements of technical viability, production efficiency, and process and environmental safety. In addition, the course provides tools for analysis of processes in operation. At the end of the course the student is able to:

1. Identify and define processing alternatives for a chemical industry, such that the following conditions are satisfied: production rate, technical viability, and process and environmental safety.
2. Evaluate different processing alternatives from the technical and economic points of view.
3. Elaborate process flowsheets and establish operating conditions for the processing steps.
4. Evaluate the technical performance of an existing process and analyse the result of implementing modifications in its operation.
5. Present preliminary projects in written and oral formats.
6. Work effectively with others as a team.

The first three objectives are focused on the development of the ability to use new information (e.g., patents) to develop feasible processing alternatives. The fourth objective is focused on the analysis of existing processes, since this is the activity most frequently performed by graduating engineers. The fifth and sixth objectives are included to reinforce the development of the so-called "transferable skills";i.e., those that once developed by the individual can be useful in a number of activities, and are essential to the engineering profession.

Figure 1 shows the general structure of the chemical process design course. The instructional activities are lectures, workshops, lectures from industry, and the development of a design project. In lectures, we explore aspects related to teamwork, process synthesis, process safety (in particular, we deeply explore the HAZOP technique), estimation of capital and manufacturing costs, and application of engineering economic.

Each lecture is followed by a workshop in which the students are organized in groups of 3 or 4, and have the opportunity to practice the concepts that were presented during the last class meeting, with the instructor and a graduate teaching assistant as "expert consultants". Finally, each semester three presenters from industry enrich the course with their experiences in chemical process design, teamwork, project management, etc. The presenters also offer feedback to the students on details of the design project that each team is developing.

We created a web page for the course [1], which serves to a double purpose. First, It allows one to maintain a quick and easy communication with students for administrative issues related to the course, such as presentation of the syllabus, grading reports, course news, and delivery of useful information, as articles of interest, the PowerPoint® presentations of lectures (which are posted in advance), web links related to the course, etc. Second, the web page provides a quick connection to selected internet resources, such as databases and online software for estimation of physical properties, databanks with information on material safety data sheets (MSDS), patents, and freeware for chemical process design. The web page is maintained by a graduate teaching assistant.

We also provide the students with access to two process simulators: CHEMCAD® from *Chemstations* [2] and SUPERPRO DESIGNER®, from *Intellipro* [3]. The latter is a steady-sate simulator, and the former allows one to simulate batch processes with special emphasis in biotechnology processes. As part of the course, the students are instructed on the use of these simulators for solving engineering problems.

3. THE DESIGN PROJECT: A SOURCE OF INDUSTRIAL COOPERATION

The subject for the design project is chosen after consultation with engineers from the local industrial area. Typically, the idea is to select a chemical of interest for some local industry for which there is some basic market study which indicates that there is some chance that the substance may constitute a successful product. Once selected the subject, the students are organized in teams and develop their design project in 12 weeks according to 4 phases:

<u>Phase 1. Design alternatives.</u> In this phase each team prepares a process flowsheet of what they consider it is the best technical option for manufacturing the selected chemical. Assessment of this phase is based on the viability and creativity of the selected option, and on the preparation of a memo that describes and justifies the selected option, summarizes a cost estimation, list assumptions made and unknown variables, and includes the process flowsheet.

<u>Phase 2. Preliminary design.</u> Each team prepares a preliminary design and perform a feasibility study. Assessment of this phase is based on a formal report that includes the process flowsheet with material and energy balances, a preliminary especification of equipment, and estimations of capital and manufacturing costs.

<u>Phase 3. Revision of safety and environmental hazards.</u> Each team develops a revision of hazards of the process designed by another team. Assessment is based on the quality and description of the process, the extension and depth of the revision, and the quality of the documentation presented. The teams use HAZOP to develop this phase.

Phase 4. Preliminary economic evaluation and final design recommendation. In the final phase, each team incorporates the safety recommendations made in the previous phase, modifies the balances and cost estimations, and prepares a final report with its design recommendation. This phase is evaluated based on the final report and on an oral presentation. Evaluation and final grading is made by a group of three engineers from industry, whom are familiar with the design subject. The final report contains:

1. A block flow diagram for the process.
2. A process flowsheet.
3. The material and energy balances necessary to specify the equipment size.
4. Estimation of the instalation costs for the equipment, and the manufacturing costs.
5. A final design recommendation and an economic evaluation of the project.

Following up and feedback provided by the engineers from industry make a significant contribution to the work of each design team. The engineers attend the presentation of each phase to provide feedback and suggestions. In addition, they act as external consultants during the development of each project. Moreover, each semester the final presentation of the projects is made to an auditorium in which there is a significant number of practicing engineers interested in the subjects. This is a very important activity in which the students have an opportunity to contrast their ideas with those of expert professionals, and practice their communication skills, among other aspects important for their professional career.

Each semester the design projects are organized in a compact disc (CD) together with information gathered during the semester by the teams, such as patents, articles, web links, etc. The purpose of each CD is to collect selected information useful to potential investors interested in the projects. Such information, of course, may be the basis for deeper studies.

The following projects have been developed in the last two years:

- Fuel alcohol from sugar-cane molasses, juice, and bagasse (11 projects).
- Lactic acid from sugar-cane molasses, juice, and bagasse (7 projects).
- Diesel fuel (biodiesel) from vegetable oils (5 projects).
- Added-value products from three industrial wastes: potatoe skin, orange skin, and pinus patula skin (3 projects).
- Products derived from chlorine (6 projects).

Each CD has been a source of interest not only for the industries directly involved in the process design course, but for others. For example, the lactic acid subject has been vigorously continued by a task-force group, the so-called "bioindustry cluster of Valle" (Valle is the state where the school is located in Colombia), in which several main industries, universities and a major sugar-cane research center participate. This group has performed detailed studies aimed to the development of a project for manufacturing lactic acid towards the production of biodegradable polymers (polylactide). We have presented more details on the lactic acid project in a Colombian conference of chemical engineering [4].

4. TEACHING STRATEGIES

The teaching strategy of the chemical process design course uses two important concepts: teamwork and cooperative learning. Firstly, it is well known that engineering is a team work activity. Thus, it is necessary to include in the curriculum some activities to develop this skill in the students, which consist in the ability of individuals to collectively handle the stresses associated to an engineering project; that is, reaching goals on time, presence of imprevisible issues during the project, distribution of work while maintainig a proper coordination of the project, satisfactory resolution of conflicts, and meeting the challenge of successfully communicate the results.

In the scheme implemented by our group, we assembly each design team looking for heterogeneity in its composition. In fact, the basic idea is that in real life, each engineer has to work succesfully with people different from him or her. Working with people with different styles is important for learning to respect and value differences, taking advantage of such differences in team´s benefit. We usually spend a couple of lectures exploring working and learning styles as represented by the Myers-Briggs type indicator [5]. We also provide the students with feedback on their teamwork skills, after observing the teams during several of the workshops developed in classroom.

The second concept is that of cooperative learning, in which the same students act as a source of learning for their classmates. We have been using the "Jigsaw" strategy [6] in which, each design team is asked to designate one member as leader in market intelligence, one as leader in process technology, and one as leader in investment project. All leaders of one area, say market intelligence, for example, receive special instruction in that area, and each leader is responsible for training his teammates in this speciality. In this way we emphasize several important aspects, as individual responsibility with the group, and interdependence.

The described strategy has several characteristics that are interesting from the educational point of view. First, the student gains a sense of pertinence of his profession, since he or she is confronted to real problems from industry. Second, the follow up and feedback provided by the engineers from industry allow the student to learn from real experience and to consider possibilities that were not taken into account previously in the process of design. Finally, all the course activities, included the possibility to contrast ideas with those of engineers experienced in the design subject, constitute an opportunity for the student to develop his or her teamwork and communication skills, an to acquire the maturity and security needed to successfully interact in the professional field.

5. CONCLUSION

The structure of the chemical process design course offered at Universidad del Valle was presented in this paper. Such structure favors the development of teamwork and communication skills, among others, by using cooperative learning techniques and cooperation with industry as central strategies. In particular, the university-industry cooperation has resulted in the development of exploratory studies of interest for the local industrial sector, and in the benefit of the professional formation of the students of Chemical Engineering.

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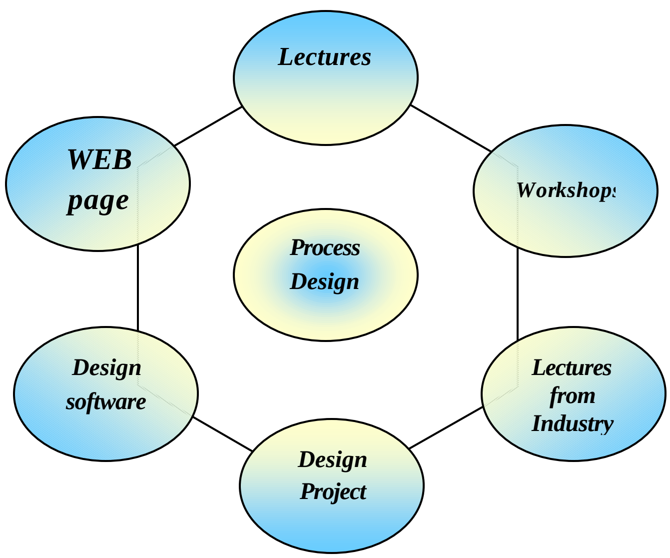

Figura 1. General structure of the chemical process design offered at Universidad del Valle.

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