Engaging Undergraduate Students in Research Projects

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Abstract **- The Chemical Engineering curriculum at the University of Coimbra comprises, in its 5th year, a final year research project which corresponds to the final requirement for accomplishment of a degree in Chemical Engineering. This project, which is distinct from the traditional Capstone Design Project, is a full year course of 30 ECTS (Eropean Credit Transfer System), which represent an average week load of 15 hours. The projects are usually conducted in a field of applied research, quite often involving an industrial partner who has conveyed to the University some kind of challenge. In this communication we will report the experience of involving final year students in applied research projects, favoring the description of projects with industrial partners, which enable a closer contact of the students with the industrial requirements. We will show the benefits for the students of being confronted with problems that do not have a standard solution. Many of those results have been presented in international conferences and some of them in international journals, always co-authored by the student. This requirement of the Chemical Engineering degree from the University of Coimbra represents an important contribution to the development of a range of important capacities in our students: critical thinking; autonomy; creativity; understanding of the industrial requirements; application of fundaments to an applied problem; communication, including English expression, etc. This practice has proved most positive, being positively assessed by the students. This course represents also a good opportunity for students exchange between the University of Coimbra and other European Universities.**

Key Words - Chemical Engineering, Research, Student Exchange, University/Industry Interaction.

INTRODUCTION

The Chemical Engineering curriculum at the University of Coimbra comprehends, in the 5th year, a final year project which corresponds to the final requirement for accomplishment of a degree in Chemical Engineering. This project is distinct from the traditional Design Project, another course also in the 5th year of the same degree. This is a common practice in many engineering curricula in European Universities (Delft University of Technology, the Netherlands; ETH, Switzerland; Erlangen University, Germany, etc.), and also in other places around the world, as is the case in the University of Cape Town [1] and in the University of Minnesota [2], just to name a couple.

The final year project has been, so far, a full year course corresponding to a total of 30 ECTS (Eropean Credit Transfer System), which represent an average week load of 15 hours. This project is usually conducted in a field of applied research, quite often involving an industrial partner who has conveyed to the University some kind of challenge.

Recently, there has been a change in the Chemical Engineering curriculum of the University of Coimbra. The final year project became a semester course and appears, now, as an alternative to an industrial training. However, that option will only be possible in the school year 2007/2008. The projects are always individual.

In this communication we will report the experience of involving final year students in applied research projects. This is, in our case, an experience of several years (more than 15 years). Moreover, in the study to be reported we have favored projects involving industrial partners, enabling a closer contact of the students with the industrial requirements.

We will show the benefits for the students of being confronted with problems that do not have a standard solution. In fact, the importance of exposing the students to this kind of problems has been recognized by several Schools and Academics [3]-[8].

In addition, many of the results from final year research projects have been presented in international conferences, and some of them in international journals, always co-authored by the student [9]-[14]. The student is required to produce a first draft of the paper, in English. In some cases the project is co-supervised by post-graduate students.

This requirement of the Chemical Engineering degree from the University of Coimbra represents an important contribution to the development of a range of important capacities in our students, such as: critical thinking; autonomy; understanding of the industrial requirements; application of fundaments to an applied problem; communication, including English expression, etc. This practice has proved most positive, being positively assessed by the students. Quite often, this course has contributed to students exchange between the University of Coimbra and other European Universities.

Furthermore, this interaction between education and research is altogether more important when we consider the new frontier areas of Chemical Engineering, where it is imperative to educate young people to go into the job market aware of these new domains, as is the case of environment protection, energy, product engineering, etc. [5,7,15,16].

In this paper we will first, present the education strategy followed in this course and, then, discuss the results

obtained. To finalize we will summarize the main conclusions resulting from this experience.

DESCRIPTION OF THE EDUCATION STRATEGY AND RESULTS

The Chemical Engineering curriculum at the University of Coimbra, which is a five year degree, has been organized till the present school year (2006/2007), according to the following scheme:
- four semesters of basic sciences (including mathematics and numerical methods, physics, chemistry and laboratory practice and informatics);
- two semesters of chemical engineering fundaments (thermodynamics, fluid dynamics, transfer phenomena, kinetics and the basics of reaction engineering and of unit operations);
- four semesters of application of the basic chemical engineering concepts (including design of unit operations and reaction engineering equipment, process systems engineering and control, particle technology and effluent treatment);
- two final semesters (9^{th} and 10^{th}) including two courses on economics and management and also a two semester course to develop a design project (this design project is developed in groups of 4 or 5 students) among others. In addition, there is another two semester course, during this last period, which constitutes the final year project (research project), representing the final requirement for accomplishment of the Chemical Engineering degree.

This structure was altered recently, the main difference, as far as the final year project is considered, being that it can be substituted by an industrial training. Nevertheless, because only during the next school year (2007/2008) the students will have the possibility of making this choice, this paper refers only to our previous experience, of more than 15 years, of engagement of students in the development of their final year projects within a broad range of research projects.

This course is shared by all the professors in the Chemical Engineering Department. Before the beginning of the school year, the teaching staff proposes a series of themes to the students, according to their competencies and current research activities, from which the students can choose the theme for their final year project. In the first week of the school year, the professors give a short oral presentation of the themes proposed and answer questions posed by the students, so that they can make an informed decision when choosing their theme. Quite often, the themes offered are in the field of applied research, resulting from problems that have been proposed by industry, this meaning that the project will then be conducted in close cooperation with industry. It must be said that, in general, these applied research projects receive the preference of the students. The projects are attributed and conducted individually.

In the remaining of this section we will give a brief description of the way these projects are conducted and present examples of previous projects.

I. Description of the Methodology

The first stage of the work is normally a literature review related to the problem posed. At the middle and end of the school year each student has to make a presentation of his work, submitting a final report at the end of the project. The oral presentations are public and all the students engaged in the course are required to be present.

Before the first oral presentation the student has to submit an extended abstract where he is required to explain the objectives of the project, present a summary of the literature review and a plan for the development of the project.

Projects can be either modeling/simulation projects or experimental projects, but, quite often, projects require both competencies on modeling and experimental. Very often, the projects proposed are related with funded research programs coordinated by the supervisor responsible for the student project. Each student has got an individual supervision but, sometimes, there can be a co-supervision by a post-graduate student working in relation with the funded program. In this way, the final year student has got the opportunity to work in an environment of research and innovation, being motivated to develop his critical thinking and creativity. Each professor is usually in charge of supervising two to four final year students per year.

Evaluation is performed by a jury of three members (three members of the staff) and, in the case of projects in co-operation with industry, another member from industry. The final rating of the project takes in consideration the two oral presentations, the report, the results obtained (degree of accomplishment of the objectives) and the supervisor information.

Supervision of the students involves periodic meetings with the student, on an individual basis (usually weekly, at least in the beginning of the project, and, later, every fortnight), for follow up of the students work. Besides, these periodic meetings contribute to exert some pressure on the student, so that he feels the need for a continuous commitment to the project.

II. Examples of Final Year Projects

In this paper we are reporting an experience of more than 15 years of supervising final year projects of Chemical Engineering students, using the methodology described above. This means supervising more than 50 final year research projects over those years. Examples of projects developed over the last five years are given below:

1. Using PCS (Photon Correlation Spectroscopy) to analyze complex samples of nanoparticles (2 papers in international congresses and 1 paper in an international scientific journal);
2. Influence of grinding on the rheology of ceramic suspensions (3 papers in international congresses and 2 papers in an international scientific journals);
3. Ageing of ceramic glaze suspensions (3 papers in international congresses and 1 paper in an international scientific journal);

4. Stabilization of ceramic glaze suspensions (2 papers in international congresses and 1 paper in an international scientific journal in preparation);
5. Using process water in the preparation of ceramic glazes (1 paper in a local congress and 2 papers in industrial journals);
6. Correlating the rheology of PVC pastes with the aggregates characteristics (2 papers in international congresses and 1 paper in an international scientific journal);
7. Monitoring flocculation of the fine particles in papermaking (3 papers in international congresses and 2 papers in international scientific journals);
8. Studies of fibre suspensions flow (1 paper in a local congress and 2 papers in international scientific journals);
9. Evaluation of the flushability of tissue papers (1 paper in an international congress).

Projects 2 to 5 were in collaboration with ceramic industries. Project 6 was in collaboration with a PVC producer and within a funded research program. Projects 7 to 9 were in collaboration with pulp and paper mills. Projects 7 and 8 were integrated in a European funded project.

The examples given above support the idea that final year students can be directed to work in a research environment with mutual benefits. The scientific papers produced are always co-authored by the students and, quite often, they are required to write, on their own, a first draft of the paper, after they finalize their project. Usually, they are quite willing to do so and this is a very good and beneficial experience for them. In fact, this is, quite often, the first scientific paper in their CV and they value this experience. Sometimes, they are also asked to attend the congress and present their work.

As a result of this involvement in a research environment, some students (probably 10 to 15% average every year) decide to go on involved in research work, sometimes proceeding for MSc or PhD.

Additionally, it must be stressed that it is quite often through this course that we manage to get involved in students exchange with other Universities. In our case, we have had during the last five years five foreign students doing their final year project under our supervision, in this course, namely in relation with projects 1, 2, 7 and 8. This is altogether more important because, in the University of Coimbra, lectures are not yet conducted in English and, thus, students' exchange is difficult with non-Portuguese speaking countries.

Moreover, these projects open, quite often, perspectives for a later more focused industrial training for the students who developed their research project in cooperation with an industrial company, as was the case for students involved in projects 2, 3, 4, 5 and 6. As far as the Faculty members are concerned, this course enables, quite often, a faster reply to the industrial challenges posed to us, by supplying, every year, a pool of human resources (the final year students) that can be allocated, almost full time, to specific problems.

Although we have not conducted a formal assessment of the students' perceptions, it is possible to conclude from the informal discussion of the students appreciation of this course, that their opinion is, in general, quite positive. They stress:

- The benefits of the co-operation of an industrial partner;
- The importance of being able to inscribe a scientific publication in their CV;
- Feeling more at ease, after completion of the project, to face new and previously unknown problems;
- Feeling more at ease to address scientific literature;
- The attractiveness and challenge of knowing they are developing new knowledge;
- The positive experience of the oral presentations for a relatively large public;
- The positive experience of working in a research team.

CONCLUSIONS

The experience reported in this paper, which refers to the integration of final year students in research projects in order to develop their final year project, as the final requirement for accomplishment of a Chemical Engineering degree (University of Coimbra) allows the following conclusions:

- It is positive for the engineering students if the final year projects are in the field of applied research; in this way, students can benefit simultaneously from a research environment and from an industrial perspective of facing the use of research;
- These projects contribute to develop several important competencies in engineering students, mainly: autonomy, critical thinking, creativity, oral communication competencies and familiarity with the use of scientific literature;
- The integration of the student in a research team allows them to finalize their engineering degree with at least one scientific publication in their CV;
- This experience helps in getting some of the students interested in research work and directing, later, their careers to research, namely to fulfill a MSc or PhD degree;
- This course represents a good opportunity for students exchange with other Universities (namely when English is not the common language in the lectures);
- Last but not the least, this course contributes to the reinforcement of manpower in research teams.

Some of these conclusions have resulted from the informal assessment conducted orally with the students and represent their main opinions.

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