A competitive collaborative learning experience in chemical plant design

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Abstract—**This paper reports on the experience of using collaborative learning techniques in a competition environment, which can be a proper approach in the traditionally highly demanding and competitive engineering courses, avoiding most of the drawbacks attributed to collaborative learning methods. The students were organized in contractor "companies" with several technical departments and a project manager, competing at every stage of the design process. The final result included some of the usual documentation of a professional basic engineering project. The results were good technically and well accepted by the students, but not all the drawbacks were removed.**

Keywords--collaborative learning; engineering course; design project; chemical engineering

I. Introduction

In recent years, the collaborative learning paradigm has been increasingly incorporated in modern engineering courses. The term collaborative learning is one of the names (e.g., cooperative learning, study groups, etc.) that encompasses a variety of learning/teaching techniques where students work together in small groups. It is frequently presented in opposition to competitive and individualistic learning, sometimes in such an enthusiastic way that forgets or even neglects [1] the benefits of the other approaches, as well as self-criticism.

Some of the advantages of this learning strategy are more comprehensive learning, lower failure and drop-out rate and a better understanding through peer discussion. Collaborative learning is said to foster creative thinking as members in a group generate new ideas, strategies, and solutions more frequently than working individually [2].

Disadvantages include (time) inefficiency, unclear hierarchical structure and unfairness in grading. Also, active resistance to collaborative methods in science and engineering courses has been reported [3].

Since the benefits of the technique have been extensively praised in the literature, in the following section we will focus on the disadvantages and false attributions that the experience described in this paper tried to avoid.

II. Drawbacks of Collaborative Learning

One of the reasons adduced to apply collaborative learning strategies in engineering instruction is that professional engineers must interact with other engineers and professionals, requiring communication, leadership and teamwork skills that are not effectively instilled by traditional teaching techniques [4]. This is true, but the statement needs qualifying:

- Apart from pathological individuals, students have been acquiring and developing social skills since they attended the kindergarten, mainly not at the school.
- In professional life, teamwork is organized around specialized personnel with a clear hierarchy where leaders have got the authority to remedy low achievement or improper behavior. This is not the case at the university, where the students are forced to deal with potentially uncooperative members.

Working in a group requires not only social skills but also organizational and management effort, what is generally not recognized enough at grading. Even when these abilities can be taught, they are built over the knowledge of what has to be managed, so young students are not the best candidates. Also, in the extremely demanding engineering courses, the managerial effort has to be detracted from other learning activities: It is generally recognized that group work usually means covering fewer topics, what should be balanced in every case against the benefits gained.

A common negative comment from students is that not all the members spend the same amount of effort in group work but they are awarded a group mark [5]. The apologists of the collaborative learning methodology would likely answer that positive interdependence has not been achieved or that task assignment was unequal, what can be solved. Those professors would possibly understand better the students' point of view by just suggesting them to get paid (only a fraction of their salary) on a department group basis.

It is difficult to find a professor that confess it, but frequently, group work means less correction work. Finally, the author cannot forget what an instructor for collaborative learning techniques told in one seminar he attended: Collaborative learning was a necessity because of our current, less motivated and less prone to effort, students.

To summarize, collaborative learning is not the panacea: It does work for some students and it does not for others, (especially at engineering schools), and it has got advantages and disadvantages. Learning, as responsibility, is always individual and collaborative learning strategies cannot be used in a general and naïf way, but are the appropriate tool for some courses and subjects. At engineering schools, they have to be carefully tuned in order to be efficient and accepted. The experience that follows, applying a competitive orientation, tried to do it.

III. THE DESIGN PROJECT

Design projects are a classic tool in engineering teaching that induces learning through doing and where collaborative learning can be applied.

The experience this paper deals with was implemented in a Separation Processes course in parallel with the development of the common topics: distillation, column trays design, liquid-liquid extraction, leaching and crystallization. The assignment was the design of a chemical process and plant based in a (part of a) real-world project for ETBE production.

A. *Organization of the work*

The students were organized in four groups (contractor companies) of five students, each one responsible of one of the five typical departments of an engineering company: project management, process design, mechanical design (columns and heat exchangers), instrumentation and piping. The project managers were the top students as by the qualifications of the tests of the first two weeks of the course. Then they have to negotiate with the rest of students to complete the company. There was no need for the professor to intervene.

The contractors received only the design basis specification and letters from the client (the professor) asking for the development of a stage of the plant design, usually affecting mainly to only one department. At the department level, at every stage of the design the four groups competed and the best solution was adopted for all the groups, providing the same starting point for the evaluation of every department. The students applied the knowledge of the course and were provided with additional information and examples for the auxiliary tasks.

The first milestone was the process flowsheet, to be developed by the process engineering departments. It implied the design of two distillation columns with eleven components, not having information about the separation sequence. The students used for the design the standard professional process simulator Aspen Plus. This is a difficult problem and the professor provided some additional orientation via e-mail and discussion meetings. The project managers of three groups assigned their best performers to this department, probably because this one is the only task directly related to the topics taught in the conventional course and it was expected arduous. The process flowsheet with the stream table is shown in figure 1, just as an indication of its complexity.

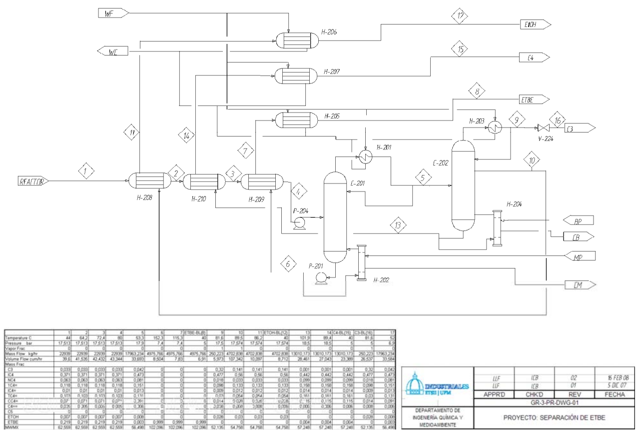

Figure 1. Process flowsheet

With the process information the rest of departments did begin their work:

- The control and instrumentation section developed an outline of the control strategy, the P&I diagrams (figure 2), the list of instruments and a preliminary study of the process safety system.
- The mechanical departments did a thermal calculation of the heat exchangers and a basic engineering design of the columns using KG-Tower, the program supplied by the company Koch-Glitsch. For every item in the list (of equipments) a specification sheet was written.
- The piping department determined de dimensions of the pipelines, drawn the plot plan and the isometric diagrams (see a sample in figure 3).

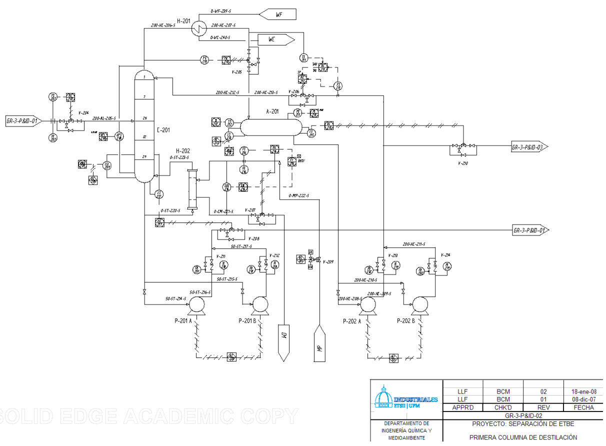

Figure 2. P & I Diagram

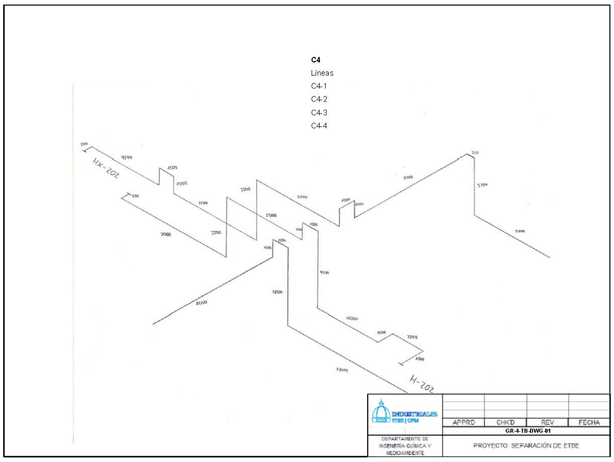

Figure 3. Piping isometric

As these tasks have to be developed almost simultaneously, there were some intermediate milestones for homogenization. The elaboration is really an integrated process were the role of the project manager, coordinating the work of his departments as well as, sometimes, the work with other groups at homogenization, was critical:

- Additional process data, as physical properties, are required for the piping and equipment design.
- The instrumentation department needs to discuss the control strategy with the process department.
- The equipment data are needed for the P&ID, the piping design and the plot plan. Note that isometric diagrams are the 3D routes of pipes in the real plant. You need to know the dimensions of the equipments and its positions in the plant.
- The piping dimensions determine the nozzle diameters of the equipment.
- Instrumentation induced connections in equipments and pipes.

Apart from the coordination function, project managers wrote an operations manual, formatted the design basis and detailed the utilities. They also collected an organized all the documents of the project.

All the documentation generated was included in a basic engineering ("black") book with around 30 documents (reports and drawings).

B. Grading policy

The general idea behind the grade structure was to avoid the drawbacks of the collaborative learning methodology, in particular the usual conflicts in groups of students that, apart from trying to learn, have to deal with the negotiations in a team where the hierarchy is diffuse or inexistent. As mentioned above, collaborative learning is generally presented as an imitation of actual professional life, but the interests and consequences of actions in the real world configure quite different scenarios.

Grading included individual and group results:

- Students that did not acted as project managers got their individual marks from the professor, their project manager and department peers at the other groups, but they only knew the final result.
- Project managers got their individual marks from the professor, their departments and project managers at other the groups, just knowing only the final result.
- The group mark was decided by the professor and a poll where all the students participated. Of course, they could not vote themselves.
- Every student got his grade by combining the group and individual marks.
- Additionally, a poll was filled by the students at the end of the project.

By letting the departments to grade the project manager and the project manager to grade the departments it was expected that a reciprocal sense of interdependency appeared, but it did not happen. The authority of the project manager was ignored several times, requiring the intervention of the professor.

IV. RESULTS

Not all the groups completed all the tasks (it was difficult) and one student abandoned in the middle of the project, but the results from the technical and instructional points of view were very good. The projects were sent to a real world international contractor company for evaluation and their comments were very positive, mentioning an "almost" professional work.

In the poll, many students answered that it was the first time that they participated in such kind of design projects, so related to professional life. That they really liked it, but they encountered the work extenuating. It was extenuating for the professor as well. The suggestion of creating a new course only for the design project was accepted and will be (hopefully) offered next year.

Some of them cited that it was unfair that there was only a winner at every stage when usually the work was quite similar, what is a criticism on the competitive orientation of the project. Actually the difference in the qualification was only extra points over the conventional mark, but they did not like the comparison.

The inclusion of incentives to keep the compromise of the students within the group was asked. Some students opined that several members of their group did not work enough, and that the mechanisms to deal with the problem were not sufficiently effective.

Almost all of the students encountered painful the change of specifications in the middle of the project (a real life problem) and asked for more information on the design methods and procedures.

The key factor for the success seems to have been the work of the project managers. The winner group was the best only at two milestones, but the final result was significantly better than the others because of the coordination and involvement of the project manager.

One of the curious issues of this learning experience is the variety of approaches and styles developed by project managers to lead their teams to achieve project goals. As it was mentioned before, project managers were the only members of the contractor groups selected applying an objective criterion. One of them, showing a surprising authoritative attitude, was partially ignored by his departments, and got a relatively bad punctuation from them. Another, using a cooperative style, was also partially ignored, but received an excellent mark from her departments. At the end, the cooperative managers got their groups develop the best projects.

V. CONCLUSIONS

The collaborative learning techniques that have been progressively incorporated in modern engineering curricula are just one of the methods that can be applied in the instruction by professors, but are not "the method". There are serious drawbacks in using collaborative learning strategies and the suspicion that some of the better results attributed to those techniques could be caused by a downgrading of the courses (at least there are less topics covered).

The experience presented in this paper tried to avoid many of the cited drawbacks, finding an appropriate case for the use of the collaborative learning methodology connected to actual professional work.

The result was good at the technical level and was well accepted by the students, but not all the goals were attained: the control of uncooperative members by the project managers using the grade policy was insufficient, and the competitive part of the design, that in part was possibly stimulating for reaching so good results, was considered unfair by some students.

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