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DEVELOPMENT OF COACHING COMPETENCIES IN STUDENTS THROUGH A PROJECT-BASED COOPERATIVE LEARNING APPROACH

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Abstract – *First-year chemical engineering students carry out a horizontally integrated design project working in teams. The teams are each led by two fourth-year students, one taking on the role of team leader and the other of knowledge manager so that the project is also vertically integrated. Team leaders facilitate project and team management while knowledge managers facilitate the learning process of first-year students in such a way that both are essentially coaches. Fourth-year students experience alternatively both roles during the two semesters (15 weeks) of the academic year. These new roles require a new set of technical and social skills: Team management, facilitative leadership, and project management skills, which are formally introduced in the fourth year Project Management course and put into practice in the Project Management in Practice course. The real challenge of the whole approach is ensuring that fourth-year students resist the temptation of reproducing the supervisory role of professors in the classical classroom environment, despite the pressure of achieving project objectives, the inexperience of first-year students who are not used to this approach, and the cultural inertia of the professors involved.*

Index terms – *Coaching skills, cooperative learning, project-based learning.*

INTRODUCTION

Historically, engineering education has mainly focused on delivering scientific and technical information to students. However, in modern corporate environments, scientific and technical knowledge can only be applied effectively if it is combined with adequate social skills and management methodologies such as team and facilitative leadership skills and project management [1].

Social skills cannot be easily addressed after graduation by additional training [2]. They are best developed across a curriculum from the introductory to the professional levels in a stepwise fashion, with appropriate repetition and positive reinforcement. In this respect, industry has repeatedly and clearly demanded that the scope of undergraduate engineering education should be accordingly broadened [3]. The message is clear, start working the above skills as soon as possible.

Project-based learning [4] coupled with cooperative learning [5] enable engineering students to combine the building of knowledge with its application to real-life problems while simultaneously developing the social skills needed in any challenging relational environment. In addition, one of the key elements for the success of any team endeavor

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is leadership. The challenge at hand is how to provide strong leadership to project teams formed by first-year students. The allocation of several professors to tutor each team is not practical given the constraints of limited faculty and budget. One alternative is to create and develop empowered student teams, ultimately capable of self-management; project teams formed by first-year students and led by senior undergraduate students who have fully experienced project-based and cooperative learning in their own education, and are equipped with team and facilitative leadership skills and project management know-how.

This paper describes how fourth-year chemical engineering students of at the School of Chemical Engineering (ETSEQ) of the University Rovira i Virgili (Tarragona, Spain), develop and practice facilitative leadership skills and apply project management methods and tools through a learning approach that combines both project-based and cooperative learning.

THE PROJECT-BASED COOPERATIVE LEARNING APPROACH

The project-based cooperative learning approach (PBCLA) at the ETSEQ has been designed to facilitate the empowerment of teams formed by four or five first-year students and two fourth-year students to carry out a design project. Figure 1 illustrates the organizational environment in which the PBCLA is implemented and takes place. The design project starts the first week of classes and lasts for the two semesters of the academic year. Thus, first-year students begin team activities when they do not possess either the necessary technical abilities and knowledge or the appropriate team-based relational skills to carry out the project.

The scope of the design project has to be defined by each project team. On the one hand, the instructors (first and fourth year professors) that participate in the PBCLA - currently the PBCLA is deployed in all first-year courses of the

chemical engineering curriculum [6], as indicated in Figure 1 - select a chemical product or a process that will be the subject of study of the design project. For instance, sulfuric acid is the current 2001/02 subject while the thermal treatment of industrial wastes was selected for the 1998/99 academic year. On the other hand, each first-year instructor selects a set of instructional objectives from his/her course syllabus, which will be not covered in the regular class hours but rather achieved through the design project. The general instructional objective fixed by the school for the first-year students is that they begin the development of lifelong-learning skills within the team-based working environment of a professional chemical engineer.

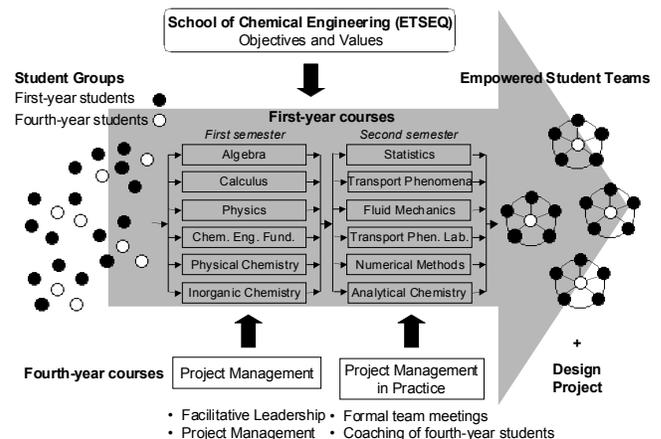


FIGURE 1

THE PROJECT-BASED COOPERATIVE LEARNING APPROACH AS DEPLOYED AT THE FIRST AND FOURTH ACADEMIC YEARS OF THE CHEMICAL ENGINEERING CURRICULUM AT THE ETSEQ.

Project teams are encouraged and guided to attain full empowerment to make decisions in all of the tasks that constitute the learning process [4]. This level of empowerment to project teams can only be granted by first-year instructors in view of the solid leadership that fourth-year students can provide. These students have accredited the knowledge needed to carry out the project activities and have already gone through the same experience a

few years ago. In addition, they have been specifically trained in facilitative leadership skills and those needed to enhance team performance [7]. However, they are now asked not to do the project activities again, that is, play the game, but rather to coach a group of first-year students through the different tasks involved in the learning process to achieve the project objectives. This new role requires that fourth-year students be equipped with facilitative leadership skills and project management know-how. This is the purpose of the Project Management (PM) course allocated in the fourth-year of the curriculum (see Figure 1).

Regarding time resources for the PBCLA, each first-year instructor dedicates between 20-50% of his/her class hours to the project so that the teams can attain their goals within the school schedule. This percentage is also the weight of the project in the first-year students' final grade in each course. The Project Management in Practice (PMP) course provides the time needed for (i) formal team meetings (3 hours per week) wherein all team members, first and fourth-year students, are present, and (ii) plenary sessions (1 hour per week) between fourth-year students and the instructors of PMP and PM. The remaining time provided by the first-year instructors, which is not dedicated to formal team meetings, is used by first-year students to carry out project activities. Instructors are present in their class hours during these activities but they are no longer responsible for any of the tasks of the learning process. They act, like fourth-year students, as coaches of the project teams.

FOURTH-YEAR STUDENTS AS COACHES

Fourth-year students take on the roles of team leaders and knowledge managers in the project teams. Team leaders help first-year students develop team skills and practice project management methods and tools. Knowledge managers do the same with problem-solving and life-long learning skills. However, neither

the team leader nor the knowledge manager works with first-year students on the learning activities that the project involves.

The specific responsibilities of teams leaders are:

- Develop and apply a method to establish the composition of project teams.
- Help the team to set its overall goal and specific objectives and develop an appropriate project plan.
- Manage the change that the PBCLA represents for first-year students.
- Help team members to clarify their roles, responsibilities, quality standards for their jobs, team norms and operational procedures.
- Manage the project and the formal team meetings.
- Facilitate the development of the team through the phases of formation, solidification and optimum team performance.
- Help the team to manage conflict.
- Develop communication and decision-making skills in team members.
- Facilitate the integration of new students into the team.
- Evaluate regularly and provide a final grade on the development of team skills and the quality of the job done by first-year students.

The responsibilities of the knowledge managers are:

- Establish a liaison with first-year instructors to clearly identify their needs and requirements on the project and to assure that the project scope is aligned with them.
- Identify first-year students' knowledge gaps.
- Devise learning activities to help first-year students to achieve by themselves the instructional objectives selected by the instructors.
- Assure that first-year students achieve the instructional objectives.
- Assist the team to connect with project stakeholders (other project teams,

instructors, professionals from industry, School's authorities, etc.) to obtain the materials and knowledge necessary to solve the project, to cooperate, to arrange for training, to obtain resources, etc.

- Evaluate regularly and provide a final grade on the knowledge acquisition by first-year students.

Additionally, both roles share the following responsibilities:

- Help the team in the application of the evaluation procedure developed by first and fourth-year students and approved by the professors participating in the project. This procedure also includes self and peer evaluation.
- Work with the professors of the PM and PMP courses to assure that the development process of the team is aligned to the School's objectives and values.

It should be noted that the roles of team leader and knowledge manager were both assumed by only one fourth-year student during the first years of application of the PBCLA [8]. The separation of roles resulted when an assessment of the approach revealed that the workload of fourth-year students was excessive. Currently, each fourth-year student alternatively assumes these roles during each semester.

The mission of the PM fourth-year course is to provide the knowledge, methods, and tools on facilitative leadership and project management to fourth-year students so that they can perform effectively their coaching roles. Table I summarizes the syllabus of the PM course, which is imparted two hours per week during the whole academic year.

TABLE I
SYLLABUS OF THE PROJECT MANAGEMENT COURSE

-
- The project-based and cooperative learning approaches.
 - The coach role.
 - Change management.
 - Project management.
 - The Team Charter.
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- Meeting management.
 - Fostering participation.
 - Effective decision-making.
 - How to provide and receive effective feedback.
 - Conflict management.
 - Facilitation tools.
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FOURTH-YEAR STUDENTS IN ACTION

The learning wheel shown in Figure 2 summarizes graphically the actions involved in the PBCLA. First-year students go through the four phases of the wheel - planning, executing, reviewing and acting - as many times as it is necessary to achieve the instructional objectives and project goals stated by first-year instructors and team leaders. Fourth-year students facilitate this cyclical journey while practicing the facilitative leadership skills and project management methods and tools learned during the training activities in team-skills provided by external resources [7], under the partnership with the Dow Chemical Co., and by the fourth-year PM and PMP courses. Teams go to phase 5 when the project has to be closed out at the end of each semester. The role of fourth-year students is described next for every phase of the learning wheel in Figure 2.

1. PLANNING

During the planning phase, the team leader and the knowledge manager form and focus the team. This is achieved by following a prescribed set of steps leading to the production of a team charter [9], similar to the one included in Table II. First and fourth-year students work jointly to elaborate each of the sections of the team charter. The contribution of fourth-year students focuses more on the identification of Specific, Measurable, Attainable, Relevant and Time-limited (SMART) objectives (section 6 of the team charter), and on the corresponding learning activities to fulfill those objectives (section 7). Fourth-year students adopt a directive leadership style (at least during the first semester) in these two items of the charter

while a problem solving style is applied in the rest of the charter items.

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4. Team member knowledge and skills profile
 5. Team's overall goal, customers, stakeholders, and products
 6. SMART objectives
 7. Action plan
 8. Tree diagram
 9. Gantt diagram
 10. Stakeholder communication strategies
 11. Team contract
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THE LEARNING WHEEL AS EMBEDDED IN THE PBCLA.

The formulation of SMART objectives aligned to the project's overall goal requires a combined effort of analysis and synthesis. Figure 3 is part of a tree diagram (section 8 of the team charter) that could represent the scope of the design project for any team. The first level of deployment of the tree is generally formed by between 5-7 objectives. These objectives are selected because they pose real design problems for the sulfuric acid process (analysis) and their resolution requires the achievement of instructional objectives from different courses in a series of integrated activities (synthesis). In the example provided, instructional objectives from calculus, algebra and physics are applied to design a tank to store the raw material sulfur.

TABLE II
CONTENT OF THE TEAM CHARTER

1. Roster
2. Rules of the team
3. Meeting logistics

Fourth-year students are fully aware from their own experience that the planning phase has to be capitalized on to manage the big change that the PBCLA represents for most of the first-year students; they have been thrust into a project team which will be led by two fourth-year students acting only as coaches and all this within a student-centered environment where instructors will also serve as coaches, offering guidance and encouragement to teams. This sudden increase in responsibility generally creates stress in both fourth-year and first-year students. Fourth-year students are reminded that the PBCLA involves the following issues:

- Greater independence from instructors and consequently greater student accountability for their learning process.
- Greater initiative from students.
- Taking on unfamiliar tasks and roles and, consequently, higher risks.

Completion of section 5 of the team charter in Table II requires that the teams discuss thoroughly the rationale of the PBCLA. Debating about the needs of instructors, who are the clients of the project, and the needs of industry as a key stakeholder help first-year students to reflect on the very human "what's in it for me" and buy-in to the PBCLA. In general, the development of the whole team charter provides the structure that a new team needs to start working and helps to create a comfortable climate that reduces the anxiety feelings that inevitably arise in students.

The last basic task of the planning phase is that fourth-year students develop the evaluation process that will be applied to themselves and to first-year students in the PBCLA. Regarding fourth-year students, the

grade obtained by applying the evaluation process is directly that of the PMP course and is used to determine the grade of the PM course. The evaluation process is the only decision that needs to be approved by all of the instructors participating in the project. Basically, the evaluation process has to be a 360 degree one and consequently, based on self-criticism, includes self and peer evaluation.

2. EXECUTING

During the execution phase of the project, the knowledge manager, with the support of the team leader, designs in more or less detail the learning activities identified in section 7 of the team charter. These activities help fourth-year students to set-up clear directions and to clarify what is expected from first-year students. Knowledge managers and team leaders should do the activities before handing them out to first-year students. Thus, they can modulate the amount of work required in each activity by providing more or fewer data depending on the time available.

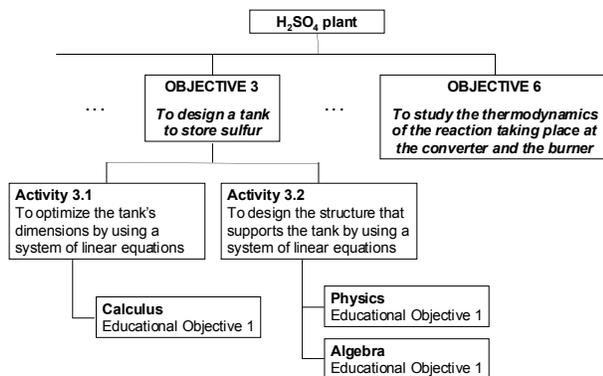


FIGURE 3

TREE DIAGRAM SHOWING PART OF THE SCOPE OF A PROJECT.

The knowledge manager and the team leader assign activities to first-year students by taking into account their knowledge and skill profiles (section 4 of the team charter) and the project progress (Gantt diagram). Generally each knowledge manager and team leader pair

applies different approaches for assigning the activities. Some assign each activity to a pair of first-year students, one of them regarded as more "capable" than the other. Others assign each activity to a responsible member that must deliver the solved activity when it is due. In this case, the whole team has to define strategies to assure personal accountability of each team member for the work done by a single student. In any event, first-year students must carry out any activity outside the time allocated to formal team meetings, either at home or during the time shared by the different project subjects.

3. REVIEWING AND 4. ACTING

The reviewing and acting phases of the learning wheel in Figure 2 take place at the formal team meetings. These are carefully planned and managed by the team leader. The main purpose of these meetings is to assess learning by first-year students and to ensure that all of them achieve all of the instructional objectives in time. This is a key responsibility of the knowledge manager. The presence of passengers in the project teams is not the problem since they are easily spotted. The challenge rather lies in the fact that when first-year students self-organize to carry out the learning activities they may specialize solely in the particular skill or set of skills (making calculations, building graphs, reporting results, etc.) that they excel at or like them most, which generally coincide.

The approach followed by most knowledge managers to ensure that all first-year students master the instructional objectives is to ask some of them to facilitate learning to the rest of team members while knowledge managers help in the process by asking questions in greater depth. This questioning process enables knowledge managers to easily assess the degree of learning of each team member. Feedback from team leaders and knowledge managers highlights the fact that at the beginning of the project most first-year students panic when asked to present orally any

material or to teach others even though they may actually master the topic. The development of both abilities is also a benefit of the PBCLA.

Team leaders and knowledge managers assess whether the objectives of any activity have been accomplished during the reviewing phase. An activity is considered as accomplished when the written resolution is correct, it has been drawn up according to the final report guidelines and all of the first-year students have achieved the instructional objectives involved. Once the activity is completed, the whole team reflects on how they have interacted to carry it out. This reflection is facilitated by both the team leader and the knowledge manager by using questionnaires that address different aspects related to the learning process, such as the design of the learning activity, the role of fourth-year students, the degree of participation of team members, etc.

The team proceeds again to the planning phase after the reviewing and acting phases are completed irrespectively of the evaluation of the activity; the team leader has to check the Gantt diagram to detect and analyze any time deviations from the plan, compute the actual number of hours invested in the learning activity, etc. Depending on the progress made on the project and the evaluation of the activity, the team leader has to decide whether or not to introduce changes into the plan, launch the next project activity/ies or continue working on the current activity if it has not yet been completed. In this case, the team will be spinning around the learning wheel until the activity is finalized. Depending on the complexity of the activity, the team can go around the wheel between 4-20 times. When all the activities of the project have been accomplished, the team moves to the closing-out of the project.

5. CLOSING OUT

A closing-out phase is systematically managed by one team of fourth-year students at the end of each semester. The purpose of this phase

goes beyond merely delivering a final report to first-year instructors. Its purpose is multifold:

1. Communicate the results achieved in the project.
2. Evaluate the performance of team members.
3. Reflect on how the team has accomplished the results: lessons learned and areas of improvement.
4. Provide positive reinforcement to students.

All project teams must deliver a final report and present and defend their results in a public poster session. During the five-hour long poster sessions, first-year students are interviewed individually by first-year instructors to assess the degree to which each student has achieved the instructional objectives. Thus, first-year instructors can grade individual team members and contrast their grades with those granted by team managers. The grade given by first-year instructors accounts for 30% of the project's grade while the remaining 70% is the responsibility of fourth-year students. In the event that the first-year-student grades given by instructors differ by more than 2 points from those given by fourth-year students, a joint meeting is called upon to solve the discrepancy. This poster session compels fourth-year students to put in place mechanisms to assure that the instructional objectives are really achieved by all first-year students and to be honest in their evaluations.

Poster sessions are an excellent opportunity to provide positive reinforcement to students and keep momentum. The experience shows that most first-year students can manage successfully the questioning by instructors and, in some cases, much to the surprise of fourth-year students. When first-year students have to explain (verbalize) what they have done and, more importantly, how it was done, they gain a deeper understanding of the material and lots of positive reinforcement is generated. In addition to this, the final poster session that is held at the end of the second semester is split into two consecutive mornings. The second one is open to everybody from university, industry, and

society in general (parents, spouses, friends, etc.). These stakeholders also discuss with students the results of their projects and how they have organized themselves to obtain those results. Finally, fourth-year students deliver symbolic, tangible objects with the ETSEQ logo printed on them to everybody attending the poster session to extend the lifespan of the experience by creating memories.

All project teams have also to report the results accomplished in the project and how these have been achieved during each semester. This closing-out written document reports the performance of team members in the project, evaluates all feedback received from instructors and stakeholders (including the grades obtained), captures all lessons learned and makes recommendations to the instructors of the PMP course for improvements of the PBCLA. After the action involved in the other four phases of the learning wheel, it is essential to force this reflection in teams. This is particularly important at the end of the first semester since teams can identify and develop ideas of improvement, and how to measure it, and apply them during the second semester.

In addition to the closing-out report, the team leader and knowledge manager deliver an oral presentation of the report to the instructors of the PMP course. The session, which is open to other fourth-year students and faculty, is an opportunity for the instructors to discuss the self and peer evaluation of fourth-year students, give feedback on technical and process related aspects of the project, assess their oral and communication skills, and provide recognition and positive reinforcement to them. This recognition is essential to call for the extra effort required from fourth-year students for making the PBCLA a success.

CHANGE MANAGEMENT IS KEY

One of the most critical items in the implementation of the PBCLA is the role of first-year instructors. As explained earlier, the instructors of the fourth year PM and PMP

courses coach fourth-year students and these, in turn, do the same with first-year students. However, the latter rely strongly on first-year instructors at the beginning of the academic year. First-year students are very sensitive to the words, body language and actions of first-year instructors. It is thus important that they refrain from conveying any premature evaluation or perception on the PBCLA or its implementation since it will weaken the trustworthiness of first-year students in fourth-year students making the task of the latter even more challenging.

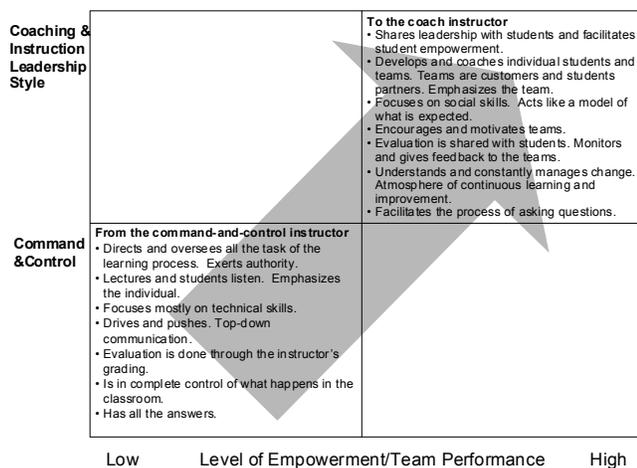
At the heart of the PBCLA is the concept of the empowerment of students. Students should assume responsibility for their own learning, create their own job profiles and gain the appropriate self-discipline and self-criticism to complete a complex task. In this environment, instructors can no longer assume a command-and-control role. Like fourth-year students, professors should take on a coach role. Figure 4 summarizes the fundamental role changes that instructors must assume in the PBCLA.

The understanding and assumption by instructors of their role change, together with the concomitant training, are essential for the success of the PBCLA. The ETSEQ has organized external non-compulsory training in team skills, cooperative learning and other effective teaching methods since 1996. In addition, the ETSEQ has intensified its partnership with the Dow Chemical Company to obtain expertise in coaching and change management skills, particularly in faculty management education. These are essential to involve faculty in effective teaching and to deploy the PBCLA across the engineering curriculum [6].

Active and passive resistance to change is something to be expected since it is inherent to human nature. Objective obstacles to change engineering education have been reported elsewhere [10]. On the other hand, the reasons to change are evident and compelling. With a strong and committed leadership and appropriate external partnerships to obtain resources, it is possible to attain the high-

impact and accelerated change like the one described in this paper.

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FIGURE 4

CHANGES IN THE ROLE OF INSTRUCTORS IN THE PBCLA

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