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Towards the Global Engineer Via the Empowerment of Students in a Project-Based Cooperative Learning Environment.

Part 1. Key Competencies and Organizational Features

by

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I. Introduction

Industry has repeatedly and clearly demanded to higher education institutions the inclusion of social skills and management methodologies amongst the objectives of undergraduate engineering education[1-3]. The prevalent opinion of current leading corporations is that, in addition to technical knowledge and skills, universities should also foster the development in undergraduate students of social skills such as leadership, creative communication, and management methodologies, including conflict facilitation and decision-making. An example of the individual competencies in the technical, social, and management methods areas adopted at the ETSEQ is given in Figure 1. It is also evident that these social skills will be needed during the whole professional careers of practicing engineers and that they cannot be easily addressed after graduation by additional continuous training or at great costs only.

The Accreditation Board for Engineering and Technology (ABET) approved in 1996 a new set of criteria (*Engineering Criteria 2000*) for accrediting engineering programs in the USA. As the ABET's executive director pointed out[4], the engineering programs of the next century must respond to the "employers' claim that engineering success today requires more than up-to-the-minute technical capability; it requires the ability to communicate, work in teams, think creatively, learn quickly, and value diversity." In Europe, the situation is very similar, and the Industrial Research and Development Advisory Committee (IRDAC) of the European Commission has also urged educational institutions to design curriculums that enhance such higher and broader competencies in students given the speed of globalization, that sense of urgency is amplified.[5]

Table I lists both the characteristics of a learning-supporting environment and the attributes of what is usually found in a classroom.[6] It becomes apparent that in such a learning-supporting environment, students would not only learn more effectively but also develop some of the competencies valued by industry and society. On the other hand, graduates from university who experience the typical classroom environment depicted in Table I generally need a few years after graduation to become effective employees. It is interesting to note that the overriding focus in the training courses organized by seven companies winners of the Malcolm Baldrige National Quality Award is on learning-by-doing rather than on the traditional university format of lecturing.[7] In addition, it is clear that quality-related skills such as customer-supplier relationships, viewing work as a process, striving for excellence and improvement, and being able to work independently and in teams can be best learned through interactive and collaborative activities.

Taking into consideration both the research of educators and the needs of industry and society, it became apparent to the professors more actively involve in promoting effective teaching methodologies at the ETSEQ that the task at hand was not merely to add a few additional courses on how to teach effectively and develop social skills into the existing engineering (program). The challenge in 1995 was rather to re-engineer the entire chemical engineering (program), including the teaching and learning processes, in such a way that science and engineering knowledge and skills could be acquired through a project-based cooperative learning approach. The first objective then was to develop, field test and evaluate an educational system based on integrated design projects. The test was performed during the second semester of 1996 and results were very encouraging. This first trial consisted in the horizontal integration of only a few first year subjects into a design project. A high level of motivation and interest in students and professors was reached but it also became clear that to maintain it after the novelty was over and, thus, to assure the sustainability of the model, the organization of the project had to vertically integrate empowered senior students as leaders of the first year teams.[8,9] Figure 2 summarizes the organizational structure and the key role that the 4th year project management and project management in practice subjects played in providing the framework to sponsor vertically integrated organization and the resources, so that clients needs could be identified and satisfied.

The following step was to aim at the integration of all first year subjects into the project and to extend the experience to all educational levels within the educational organization. Simultaneously a partnership with The Dow Chemical Company was established to obtain leadership support and expertise in the areas of change management, team performance, and quality improvement. These areas were considered crucial for the development of the novel educational system where both technical and social skills would be considered as important. The preliminary results of the aforementioned industry-education partnership to foster global change across our academic organization were presented at related conferences[10,11] during 2000.

The purpose of this paper is to identify the critical social skills that are needed in an empowered system to educate global engineers, and to design, in collaboration with The Dow Chemical Company, an educational model for the ETSEQ that applies those skills also to enable the development of technical and scientific competencies, which is one step beyond their consideration as important but mere additional instructional objectives. The selection of social skills is carried out from the sponsors perspective in the integrated design project sketched in Figure 2, so that the culture of this project spreads from the 1st year naturally as students advance in the curriculum and assume personal responsibility to facilitate their implementation when they reach the 4th year of chemical engineering education, just before completing their education successfully by the end of the 5th year of the program. Section two lists the competencies recognized both as critical and as enablers for technical competence. They are defined and classified as suitable for embedded development during the project-based cooperative learning activities or for external interventions. Section three presents the organizational structure where the new teaching and learning project-based methodology is implemented and social competencies developed together with technical competence. Finally, the main conclusions drawn from the experience are presented. The current work does not necessarily provide details on the best practices to promote student learning and the development of skills because they have been summarized in the excellent series of six articles on the Future of Engineering Education published in this journal[12-17]. Most of these effective instructional methods are embedded in the project-based cooperative learning approach adopted at the ETSEQ to reform engineering education, and are the basis for the development of the proposed set of nine critical social skills.

It should be noted that the Department of Chemical Engineering of Tarragona had already established a partnership in 1988 with the local chemical manufacturers association, which includes the most important chemical producers worldwide, to develop, field test, and implement the APQUA chemical education program[18]. This program is an adaptation of the Science Education for Public Understanding Program (SEPUP) approach conceived and designed at the Lawrence Hall of Science of the University of California at Berkeley to teach science in high schools. The approach is student centred and it involves activities and investigations, discussions and debates, and themes and questions, so that students acquire scientific and social concepts and skills, at the same time as they become independent thinkers and active participants in science and society. They experience the relation of science and technology to social issues while they gather and evaluate scientific evidence, assess risks and benefits, ask questions, and make decisions based on evidence rather than emotion. Further information about the SEPUP program and inquiry-based science education can be found elsewhere[19,20].

II. Competencies to be developed by chemical engineering students at ETSEQ

Social skills have a strong relationship with procedures, attitudes, values and norms. The continuous improvement program at the ETSEQ states that all activities and processes carried out have to conform the following set of cores values:

(i) We are a team where people are the most important part.

(ii) A commitment to serve the community beyond the expectations of stakeholders.

(iii) Efficiency, reliability and responsibility.

(iv) Excellence in the generation and dissemination of knowledge.

(v) Entrepreneurship, initiative, dynamism, versatility and adaptability.

The first value concerns both shareholders (students, professors, and technical and administration staff) and stakeholders (parents, employers, tax-payers/government). It evolves from the compromise of the ETSEQ with a student-centered educational system, based on teamwork, where each individual involved attains the full development of its potential capabilities. In this context, self-evaluation is a fundamental tool and also a process that encompasses three pillars of adult life: Self-criticism, self-knowledge and self-affirmation. This is the framework within which the ETSEQ has progressively identified the key knowledge, skills, attitudes and processes to be learned during undergraduate and graduate engineering education. In this process, the technical, methodological and social aspects related to the competency concept that is increasingly used by companies to guide decision-making in issues related to human resources development[7] have also been considered. A competency may be defined as a cluster of related knowledge, skills, attitudes and behaviors that affects a major part of one's job. It should be correlated with the performance on the job , be measured against well-accepted standards, and be improved via training and development.[8] The latter characteristic is obviously very interesting for an educational institution.

The set of nine social key competencies given below are aligned with the above ETSEQ values and have been selected from the skills found to be crucial for successful development of the integrated design project carried out by teams of 1st and 4th year students[9] within the organizational framework of Figure 1, and from the opinion of several chemical corporations and educators[1-4,6,9].

- Client orientation:. The ability to identify and listen actively to clients, to anticipate and identify what clients need and value, and to seize opportunities in a responsive manner.
- Team players: The capability to contribute to effective team output by cooperation, participation and a commitment to share vision and goals, achieving interdependence with personal accountability.
- Continuous improvement and innovation:. The ability to strive to improve continuously and to generate novel and valuable ideas or apply existing ones in new ways. Also, the capability to apply creativity to solve problems, to have a bias for action, and to take appropriate risks.
- Facilitative Leadership:. The ability to help other people to improve performance, to promote an environment that fosters the development of others, to influence and guide others toward identifying and achieving objectives, to provide purpose and direction, and to motivate and enthuse others.
- Work management:. The capability to organize and manage work with the purpose of achieving objectives (results) and meeting deadlines, based on an understanding of organizational dynamics.
- Responsibility and Active learners:. The attribute by which people become owners of their organization results, able to make decisions, and able to work according to agreed quality standards. The ability to seek for opportunities to acquire relevant knowledge, to challenge and to use critical thinking, and to develop personal abilities. Also, the desire to improve individual performance and to reach full potential.
- Communication and Human Interaction: The ability to communicate effectively with all people, to deal with controversial dialogue, and to present and facilitate a variety of materials, meetings and workshops.

- Systemic and independent thinkers:. The ability to deliver technical capability based on a vision of the big picture and to manage any individual or collective endeavor according to a holistic model. The capacity to recognize patterns.
- Cultural background and diversity:. The ability to deal effectively with conflicts caused by cultural background and diversity, and to facilitate reconciliation, based on the understanding of differences in cultures, norms and value systems.

These nine social competencies should be enablers for technical competence. They are also closely related to the fundamental concepts of the Malcolm Baldrige and European Quality Awards[10]:

III. The social competencies within the integrated team-based design project

Let us examine first in more detail the meaning of the adjectives integrated and team-based to better understand the distinctive features of the current approach, which gravitates around the 1st-4th year design project depicted in Figure 1. A detailed description of this experience is presented elsewhere[9]. The 1st-4th year design project involves horizontally all twelve 1st–year subjects and vertically at least two 4th-year subjects, Project Management (PM) and Project Management in Practice (PMP). Each participant in the experience plays a certain role. Professors of the 4th-year courses act as *sponsors* of the project and form the Project Board, the body to which project leaders and knowledge Managers are accountable for meeting clients' needs and requirements within the academic framework and with the resources set by the ETSEQ authorities. Then, there are several *project teams* composed out of one *project leader* and one knowledge Manager (fourth-year students) and 4 *team members* (first-year students), with the objective of carrying out a given design project, which is common to all teams. Professors of the first-year subjects are the *clients* of the project because they want to see how first-year students apply the knowledge and concepts of their respective subjects into the project. In addition, 1st-year professors along with the rest of ETSEQ faculty and professionals from industry act as *consultants*, that is, people whom team members may address for technical support and coaching.

In what follows, several aspects of the 1st-4th year design project are discussed in detail in order to illustrate how working in the project helps students to develop the competencies listed presented in Section 2.

a) Client orientation

Customer-driven quality, listening to the voice of the customer, identifying customers, and customer-supplier relationships are among the seven most important quality-related concepts and skills valued by Malcolm Baldrige winners[6]. In order to instill this competence in our students, it became apparent to us that project clients should be real and accessible so that our students could interact easily with them. The main clients of the design project are the professors of the 1st-year subjects involved. At the beginning of each academic year, these professors meet to draw up a project charter and to negotiate their degree of involvement in the project[14]. The purpose of the project must be very open (usually 2 or 3 short sentences) so that the content of the different subjects can be applied in the project. Professors who accept to participate in the project cede between 25% and 50% of the class hours per week to project teams for doing the project. They expect that 1st-year students will apply into the project part of the instructional objectives of their subjects. These instructional objectives are therefore the clients' requisites on the project and help team leaders to define the project scope. Every first-year professor participating in the project hands out, at the beginning of the semester, a syllabus of the subject together with the associated instructional objectives.

On the other hand, as soon as team leaders start working on project management, that is, writing the project charter[18], they must identify who the project clients are and identify their needs and requisites. The answers given to these items are usually far away from what one would expect. Typical initial answers are the society in general, the regional environmental agency, the chemical industry, etc. However, when asked who is going to use and "pay" for their project products, there is no hesitation in the answer: professors of the 1st-year subjects. Thus, team leaders start to think how to satisfy the expectations of 1st-year professors. As an example, team leaders in the 1998-99 academic year wrote a contract that was also signed by clients. The basis for the contract was a tree diagram to define the project scope as well as the corresponding checklist where instructional objectives were associated to work packages in the tree diagram. Project clients could therefore visualize how their instructional objectives were integrated in the project scope.

Students learn that, as in any real-world experience, some clients are more collaborative than others. A professor who has already provided specific instructional objectives may change his/her mind during the scope-setting phase, or even during project execution. The attitude of such professors upsets most of the 4th-year students. Complaints such as "you cannot expect me to plan if you are not able to do so" or "this is chaos!" are common during the scope-setting phase. In other experiences[17], part of the role-playing for the clients involves to act deliberately unfriendly, or even unreasonably, to force students to negotiate. However, these experiences are eventually the most rewarding ones since they trigger creativity in our students and foster preventive thinking and preparing contingency plans. In the end, the sometimes unreasonable or contradictory clients are necessary to achieve meta-learning. As concluded by David Lei et al.[19], meta-learning is necessary to develop and sustain effective dynamic core competencies such as client orientation.

b) Team players

Project teams formed by one project leader, who is a 4th-year student, and 4-5 1st-year students acting as team members, carry out the integrated design project. This arrangement represents a breakthrough with respect to other project experiences. The team-based design project approach is increasingly being applied in Engineering Schools, even from the first year[15]. However, projects are generally carried out by classmates and the limits of the project are those of the subject in which they are enrolled to.[16, 17] This is not the case at ETSEQ, at least for the first year of the program. In the 1st-4th year project, 4th-year students are given the opportunity to experiment in a real human lab, leading a team of 1st-year students, that will allow them to boost social skills and to role-model those competencies appearing in Fig. 1 to 1st-year students.

Team members are assigned to team leaders during the first week of the first semester. Fourth-year students are given the opportunity to participate in the team forming process and to readjust/exchange team members during the second week to account for any constraint on 1st-year students. Project teams must be built by leaders from scratch since all team members are unfamiliar with each other. Therefore, this is an excellent opportunity for team leaders to develop their interpersonal skills. In this experience, they are not among well-known classmates working together on a small project within the limits of a specific subject. Team leaders understand that what they do builds (or destroys) trust and successful relationships and that nothing can be taken for granted.

The group of 4th-year students also works in teams in the PM subject to devise best strategies and use most suitable tools for effective group dynamics, project management, and use of quality tools. In addition, 4th-year students also form a team that is responsible for communicating periodically with the project clients so as to keep project's scope under control and to probe client's satisfaction with project's progress. Team leaders meet with their teams at least 3 hours per week in the first and 4th-year classrooms. During the remainder of the hours allocated to the project, 1st-year students are at hand working on their own in their corresponding teams. In these team meetings where leaders are absent, a 1st-year student, in a rotary fashion, leads the meeting using the same tools and procedures employed by his/her team leader.

Teams establish ground rules, identify project's clients and stakeholders, prepare agendas and minutes, manage "parking lots", decide how to give and receive feed-back, etc. However, team leaders are not obliged to stick to the book recommended in the PM course[20], but are rather encouraged to experiment. For example, what might happen if one leader shows up in a meeting without an agenda? During the project closeout presentations, some leaders argued that they did not prepare meeting agendas during the first few weeks because they felt it was unnecessary. However, they recognized that they had to eventually use written agendas, and not only because of the obvious reason of having more effective meetings but also because their role as leaders was highly enhanced. Team members' realization that the leader was well organized and that he/she had invested some time to plan the meeting conveyed a trustful image.

c) Continuous improvement and innovation

Continuous improvement, as well as the rest of basic Total Quality Management (TQM) principles, is instilled in team leaders through self-assessment exercises carried out individually within the PM subject. As it happens with many organizations around Europe, self-assessment against the criteria of the European Quality Award (EQA) model[21] has also proven to be appropriate for team leaders in order to identify strengths and areas of improvement, and to put improvement plans into action. Somehow, team leaders regard project teams as small engineering companies.

Team leaders when performing a self-assessment exercise try to understand and to apply the EQA model in the light of their team-based project experience. For instance, one of the areas to address under sub-criterion 1(a) reads: “how leaders review and improve the effectiveness of their own leadership”. Team leaders realize that they should get team members’ feedback about their leadership style in order to improve it. Then, some team leaders develop a questionnaire to measure team members’ satisfaction with different aspects of the project, including leader’s effectiveness. The following step is the establishment of partnerships among team leaders in order to compare results and best practices, that is, cooperation and benchmarking start to flourish.

Continuous improvement, and in general TQM principles, permeates into 1st-year students through team leaders’ behavior and actions. First-year students do not even suspect the existence of neither the self-assessment concept nor the EQA model, let alone TQM principles; however, they live them through the way team leaders do things. It has also to be pointed out that both project management and team working methodologies employed by team leaders are designed according to TQM principles[18, 20].

d) Facilitative Leadership skills

Fourth-year students take over quite naturally the leadership role because 1st-year students see them as the ones who have already passed successfully for the experience and who also have much more technical knowledge. Team leaders develop skills mainly in the following areas: building trust, encouraging initiative, coaching, leading effective meetings, planning, giving and receiving feedback, and appraising people’s performance and reconciling conflicts.

In the very beginning of the project, there are always a few critical team leaders who complain that 1st-year students are, in general, poorly prepared, and that the purpose of the project is beyond their capabilities. Furthermore, they contend that their responsibility should be only to manage the project, and not to coach students. It is therefore necessary to put the stress on two key points of the project. First, teams are empowered to establish their own objectives for the project, that is, to define its scope. Project clients expect to get a final product appropriate to 1st-year students’ knowledge level. The real concern of team leaders is the fear to freedom, as they would probably prefer clients, sponsors or anybody else define the project scope. Second, team leaders are also learning when coaching team members since they must first clearly understand the concepts and, consequently, this is an excellent opportunity to get a profound knowledge of 1st-year subjects. In fact, many team leaders confessed that they grasped for the first time a good deal of 1st-year concepts.

Team leaders must also assess the performance of team members. They are responsible for devising, early in the project, a grading system for appraising team members' performance. Their marks account for 80-100% of the total score allocated to the project by clients (this varies between 25 and 50% of the course total score in correspondence to the number of hours allocated to the project). Consequently, team leaders' marks may be key for 1st-year students to pass a course, lifting up team leaders' feeling of responsibility. The discussions among team leaders around which criteria to use for appraising team members are always inspiring ones. Some team leaders support the use of tests for assessing team members, trying to reproduce what they have endured in many courses. Others put in question this system raising motivation and recognition issues and taking into account total quality principles. Project sponsors facilitate these discussions and the only recommendation given to team leaders is to include as items of the grading system a self-assessment by 1st year students and a cross-evaluation among the latter.

Team leaders also understand that they must help team members to think by themselves. At the end of the semester, teams must present a poster and defend their results. Clients interview teams members individually. In the event that the score given to team members by clients differs considerably from the score given by team leaders, the leaders' mark in the PMP and PM subjects would be negatively affected. This compels leaders to put in place procedures to assure that the instructional concepts applied in the project are really understood by all team members. By the same token, team leaders are refrained from doing part of the project tasks by themselves. Team leaders must enthuse 1st-year students and involve them in the project. For 1st-year students this experience is radically different to whatever they did in their previous studies. For this reason, team leaders are provided with information on the rationale behind this innovative teaching and learning methodology. Moreover, sponsors reassure team leaders in that they will not be alone in their efforts since resources and assistance will be provided as needed through the PM and PMP subjects.

e) Managing work

In addition to be technically competent, our students also learn to organize and manage work to achieve results. The management practice feeds directly from the PM course, which includes in its syllabus project management and teamwork methodologies, and quality principles and tools. Project teams proceed through the various phases of project management[18], i.e., elaboration of the project charter, planning, execution, and closure of the project, and apply different tools such as brainstorming, affinity diagrams, tree diagrams, PDPC's, and Gantt charts.[22]

Planning and application of the Deming's Plan-Do-Check-Act circle[23] do not come naturally to students and to most of faculty members. When the project starts, some 4th-year students genuinely believe that planning is a complete waste of time. They would directly jump to the execution phase as soon as they get an idea of what is required in the project. This had always been the way of doing things before entering this experience, and this modus operandi is firmly ingrained in their minds. Furthermore, some clients encourage them to skip the planning phase and to start doing some "serious" work. The attitude and words of such clients might undermine the morale of those team leaders that are willing to plan and, in general, to try new things. Sponsors must be watchful in the early stages of the project, as innovative team leaders are essential for the success of the experience. They will experience the benefits of planning, and will eventually serve as role models to the skeptical and to the nonbelievers. The development of a project plan facilitates the problem-solving process[24], and is equally important in enhancing team leaders' image and in reducing team members' anxiety. Students must discover these benefits by themselves; this is the only way of changing their behaviors. As Russell Justice emphasizes "behavior is not a function of procedure; behavior is a function of consequences."[25]

f) Responsibility and Active learners

Teams are responsible for the project and are empowered to make decisions, put in action their ideas, and take appropriate risks. At the beginning of the project this is easier said than done since, in general, both team leaders and team members feel rather overwhelmed with their new roles. Team leaders understand that they are key players in the team success and, consequently, in helping 1st-year students to pass 1st-year courses. First-year students suddenly realize that faculty will be there as a resource that they can make use of, but also that it is up to them to take the initiative.

When students understand and appreciate how they learn, a phenomenon called meta cognition, they become increasingly responsible.2[5] With the integrated team-based project, learning responsibility is cascaded down from faculty to team leaders, and from these to team members. Team leaders can closely monitor which concepts team members really know and which are not totally understood. Then, team leaders can examine how team members have learned it and, consequently, they can devise alternative individual teaching strategies for their team members. This process helps team leaders to gain a better understanding of how their team members learn and, eventually, how they learn themselves. First-year students are offered the choice of learning from their professors, from their team leaders, and even more important from their teammates. As David Pines says, "always encourage students to learn from one another."[26] Definitively, students are learning how to learn.

g) Systemic and independent thinkers

Traditionally, learning takes place in unrelated, disconnected courses. As Peter M. Senge puts it, since childhood we are taught how to divide the world up into small fragments so that they fit into the little boxes that we have built[27]. To see the general picture means to assemble again the small fragment and to enumerate and organize all the pieces. The reality is that even well trained graduating engineers usually lack the skill to apply their knowledge to solving a real-world problem.[28]

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The integrated design project functions like a magnet that aligns the content of the different 1st-year courses, including a laboratory course, towards the resolution of a real-life problem[13]. First-year students, guided by their leaders, are constantly looking for ways of applying as many instructional objectives as possible in the project. This effort makes first-year students be able to synthesize what they have learnt to solve a problem. Moreover, their learning is much more effective since they are bound to practice the higher level thinking skills of Bloom's taxonomy.[11]

In addition, team leaders benefit from self-assessments against the European Quality Award (EQA) model to enhance their systemic thinking. The interrelationships among different aspects of the project are made visible by applying and understanding the EQA model. Thus, team leaders realize that the project is not only a technical problem to be solved, but it is also leadership, planning, people management, resources management, critical processes management, client satisfaction, people satisfaction, impact on society, and project results.[21]

h) Communication and Human Interaction

Communication skills have been identified as one of the most important competencies that should be developed in students. In fact, it results impossible to think of a good leader that is not also an effective and creative communicator. For this reason, one hour per week of the PMP subject is devoted to oral presentations given by 4th-year students. The purpose of these presentations is that team leaders share best practices, project pitfalls, difficulties with 1st-year students, etc. Afterwards, classmates and professors give feedback about how to improve whatever aspect related to the presentation itself. During the project, every 4th-year student gives several short oral presentations and a final presentation to the sponsors at the end of each the semester. In addition, team leaders deliver three different written reports. In the first report, delivered after the first 3-4 weeks, they present a proposal for the exact project scope, as agreed to by the team, and the grading criteria to be applied to each team member. These items are then negotiated in a meeting with professors where a definite common proposal is approved. In the second report, handed after 5-6 weeks, 4th year students present the planning of the project for the remainder of the semester. Finally, they deliver a final written report including a self-assessment of their own performance and the evaluation of each 1st-year student in their team. In the PMP subject, the closeout report also includes strengths and areas for improvement of the integrated team-base design project that are taken into account by project sponsors to improve the experience for the next academic year.

Regarding 1st-year students, all teams deliver an extensive technical report and present publicly their results during two 5-hour long poster sessions, open to everybody from university, industry, and society in general. Team leaders are responsible for organizing these sessions and for identifying and involving ETSEQ key stakeholders, particularly people from industry. These sessions are an excellent opportunity to provide positive reinforcement to students. Professors and professionals from industry discuss with students the results of their project, but equally important, how they have arrived to those results, i.e., their processes and attitudes. This event is a powerful learning experience since as Dingus and Justice put it, "listening is teaching; talking is learning."[29] Moreover, team leaders deliver symbolic, tangible objects with the ETSEQ logo printed on them to 1st-year student in order to extend the life of the experience by creating memories. Also, from a Change Management perspective, this is an important "ritual and symbol", to publicly reward and recognize team work and consequently drive culture change [Literature: William Bridges Managing Transition, Perseus Publishing]

IV. The overall project-based cooperative leaning model

Once the core social competencies for 1st and 4th year students have been identified, the challenge is to design the educational organization, including the 2nd, 3rd and 5th years of the program, and the corresponding social-skill teaching interventions that are needed to develop such competencies while providing value-added technical competence[6].

Figure 3 shows a typical scheme under evolution at the ETSEQ Q) to attain the educational objectives mentioned before and the above competencies. This scheme should also allow the empowerment of students within the organization. To make this system sustainable and capable of self-improvement, an integrated, team-based design project has been deployed and allows it to flow-through and retro-feed. Students at ETSEQ perform an integrated team-based design project for each one of the five years of the ChE undergraduate program. There are two reasons for starting from the very first year. First, as students are progressing through the ChE program, they are taken through what is called the six levels of Bloom's taxonomy[11]: knowledge, comprehension, application, analysis, synthesis, and evaluation, and the scope of the design project is posed accordingly to the year of the ChE program. When graduating, students should be able to apply what they have learnt to solve a real-world problem, in other words, be technically competent. Second, competencies are best developed across a curriculum from introductory levels to professional levels in a stepwise fashion, with appropriate reinforcement and completeness.[12] This approach is also supported from an organizational change perspective, as all parts of the organization (University) are engaged and consequently a "two class society syndrome" can be avoided.

V. Concluding remarks

Students cannot develop industry-valued competencies nor learn effectively in a traditional classroom environment only that is based mainly on lecturing different topics that have been artificially pigeonholed in several isolated courses. Emphasis must be shifted to learning-by-doing approaches, such as the integrated team-based design project, in which students interact and cooperate to solve "real-world" problems, and this must be started from the very first year of the program. Students also enjoy quality principles and develop quality-related competencies without any specific TQM course or similar The teaching and learning approach itself allows students to experiment quality tools, models of excellence, and to build a culture of quality in their teams. They live the quality principles, not only listen to abstract philosophies. Hopefully, and this is already happening, they will apply quality principles in every organization in which they will be involved.

The extensive use of the integrated team-based approach across the whole curriculum brings about a new paradigm at ETSEQ . The commitment and cooperation of several professors in a common purpose means indeed a significant cultural change since it starts breaking down the typical “non-collaborative hero culture” attached to faculty. Their role is changing dramatically too, passing from being rather “supervisors” into being “coaches and consultants.” They must shift also their focus, recognizing that the processes and attitudes to achieve technical results are as important as the results themselves. On the other hand, students are developing competencies that some professors do not possess and this may become a cause of concern for the latter. Has each professor built and led a team? Has each professor managed a project? Is each professor client oriented? This forces professors to increase their skills as well, beyond their traditional expertise. As in any other change experience, the existence of a strong and committed leadership is key for driving the transformation, supporting everybody in the journey, and avoiding regression into the lecturing format.

The implementation within the ETSEQ of the team-based project system, sketched in Fig. 3 above, offers extraordinary opportunities to innovate. It is thanks to this approach that 4th-year students can conduct self-assessments against the criteria of the EQA model in the Project Management subject. Fourth-year students are learning a model of business excellence based on TQM principles by applying it to their small engineering businesses, i.e., their project teams. Moreover, self-assessment is, in our opinion, key for students’ journey towards empowerment. Teams not only evaluate their performance but they also realize what are they needs in terms of decision-making. That is, self-assessment very often leads students to the idea that in order to improve continuously their decision-making scope must be widened.

Thus, an increasingly larger amount of organizational responsibilities must be transferred from the ETSEQ authorities into students. The complete empowerment of the student body and individuals is perceived as a key factor for the future success of the ETSEQ. We want our students to be responsible for their own learning, to take the initiative and make decisions constantly, to be encouraged to learn from each other, and to participate more and more in the management of many critical processes of their school. In other words, students are being gradually empowered to become owners of their school. Our task is to train graduates to become, and, empowered, committed, and accountable individuals, not just “workers” for employers . Otherwise, how can we expect them to integrate effectively into the industry? However, the required transfer of responsibilities towards students is meaningless unless they are actually willing to take it. To instill such willingness into our students – in order to obtain sustainability - is perhaps the main longterm objective that is being pursued with the team-based educational deployment that has been presented here.

V. Outlook and Future Perspective

Our journey in preparing “The new Global Engineer” has been very challenging, yet very rewarding. The results and the feedback obtained so far have not only encouraged us to continue, but even to boost our activities. Therefore we have intensified our partnership with industry (in particular The Dow Chemical Company) to obtain particular expertise and especially tools and also injecting particular skill building like coaching skills for the team leaders and knowledge managers. Over the next two years we will intensify our efforts by providing our project teams with appropriate enhancing team performance tools. In addition our plan calls for an upgrade in leadership skills by faculty members and additional measures on an organizational level to accelerate the necessary culture change. We are confident that theses efforts result in truly building the skills, competencies and behaviors for the “Global Engineer”, meeting the challenges of tomorrow’s world.

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Table I. Characteristics of the environment in which learning take place against what is usually found in a classroom.

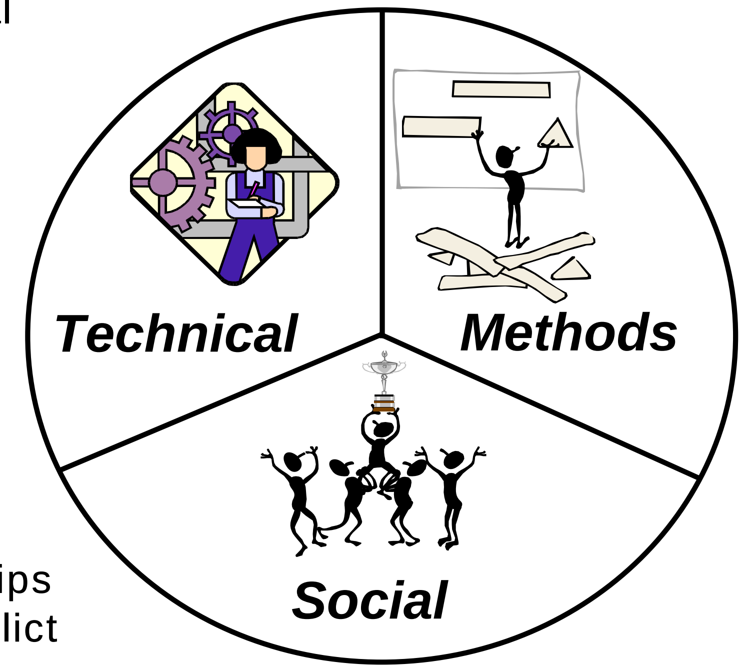
Learning-supporting characteristics	A typical classroom environment
- Lively interaction with others	- The teacher lectures and students listen
- A sense of teamwork	- Students generally work alone
- An understanding of purpose	- The purpose is unclear or unknown by students
- A passion for learning	- Students have a passive attitude toward learning
- Immediate feedback	- Evaluation is done through the teacher's grading
- Active participation	- Students' participation is passive
- Encouragement for risk taking	- Students prefer to take the safest route
- A sense of connectedness with the task and its meaning	- Students feel disconnected from the task and its meaning
- A feeling of responsibility for the outcome	- The teacher feels responsible for the outcome

Source:

Barbara A. Cleary, "Relearning the Learning Process," *Quality Progress*, April 1996, pp. 79-85.

- Knowledge and Technical competence in Chemical Engineering

- Problem solving
- Self-organization
- Decision-making
- Presentation
- Facilitation



- Team work
- Inter-personal relationships
- Communication and Conflict Resolution
- Empowerment
- Leadership

Figure 1. Elements of individual competency as defined at the ETSEQ

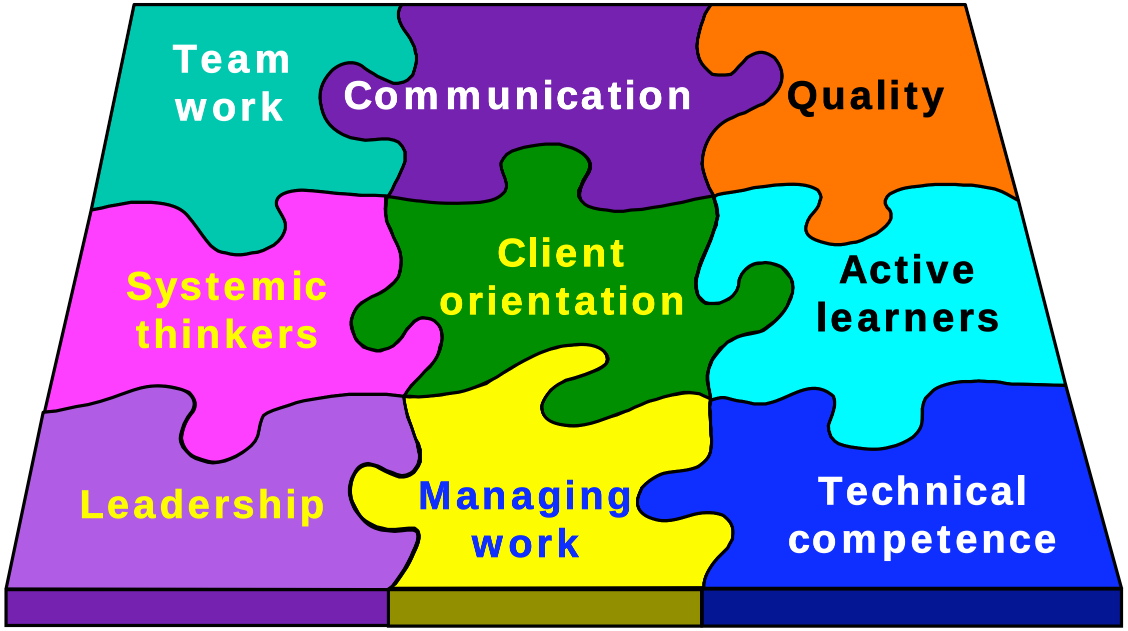


Figure 2. Key competencies to be fostered in our students through the teaching and learning methodology introduced in this paper.

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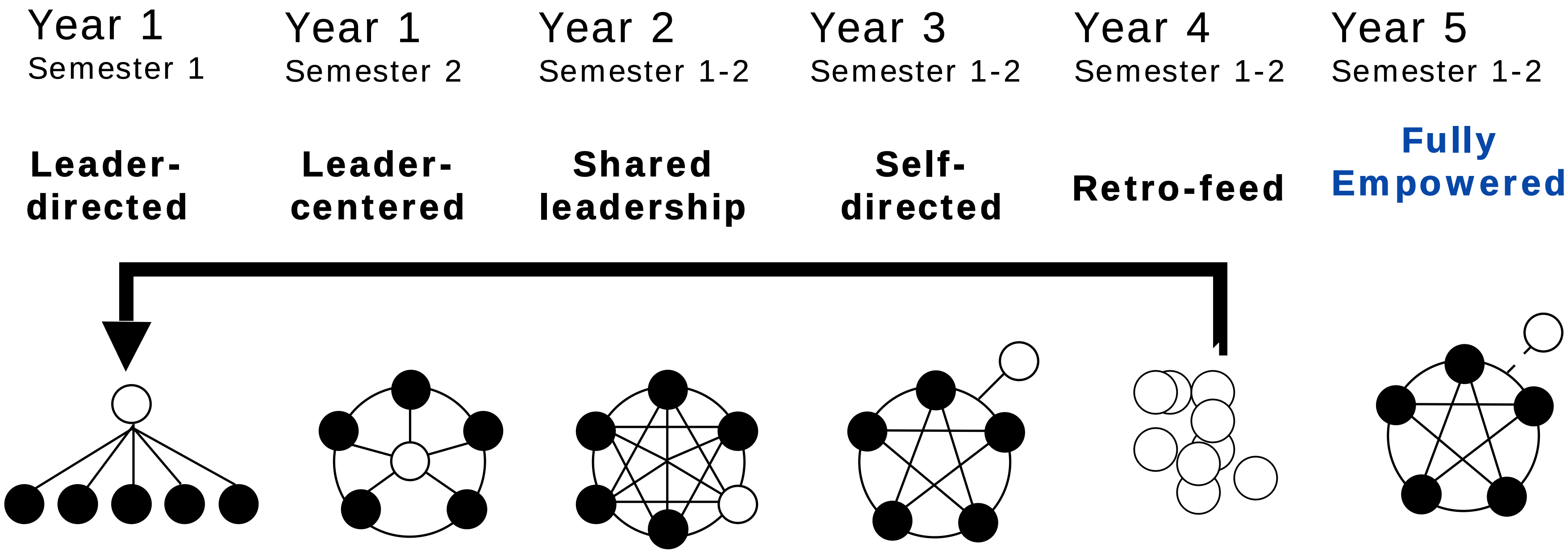

The 5 stages of Empowerment

Figure 3. Evolution of team work organization in the Chemical Engineering studies at the ETSEQ. A 5E HA DE SER UN PROFE: BOLA MÉS GRAN

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