VIRTUAL PROFESSIONAL ENVIRONMENT: A METHOD FOR THE EDUCATION AND EVALUATION THROUGH COMPETENCIES.

Francisco José Suñé Grande

Dipòsit Legal: T 271-2015

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VIRTUAL PROFESSIONAL ENVIRONMENT: A METHOD FOR THE EDUCATION AND EVALUATION THROUGH COMPETENCIES

DOCTORAL THESIS

supervised by Dr. Josep Bonet Àvalos and Dr. Hans J. Witt

Department of Chemical Engineering

UNIVERSITAT ROVIRA I VIRGILI

Tarragona

2014

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We STATE that the present study entitled "VIRTUAL PROFESSIONAL ENVIRONMENT: A METHOD FOR THE EDUCATION AND EVALUATION THROUGH COMPETENCIES", presented by Francisco José Suñé Grande for the award of the degree of Doctor, has been carried out under our supervision at the Department of Chemical Engineering of this university, and it fulfils all the requirements to be eligible for the European Doctorate Award.

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Tarragona, December 2014

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Abstract

Social competencies play an ever increasing role in the professional activity of engineers. Many institutions of studies accreditation (ABET, IChemE, EUR-ACE, etc.) emphasize the need to educate the future engineers on these competencies, along with on the traditional technical competencies. However, due to the intrinsic complexity of devising a way of teaching and practicing social competencies, we have to add the task of a reliable assessment of the students' social competency level. In this thesis, we introduce the initiative taken at the ETSEQ for a systematic and objective method of social competency assessment. We review and discuss the results from the application of the method to the entire degree of Chemical Engineering of the ETSEQ, involving approximately 300 students and 25 staff members during the 2013-2014 campaign. We also take into account the results obtained in the previous pilot test conducted during the second semester of 2012-2013.

The assessment is epistemologically centered on what the student does and can be observed, as the objective indicator of what is expected from a socially competent engineer. The action takes place in the context of the Integrated Projects carried on during the studies. Since human behavior is intrinsically variable and the observation, subjective, we have introduced a 360º survey. This way, the repeated input, along with the frequency of observations collected, assures that the average of the grades obtained has a significant reflection of what the social competencies of the student truly are.

The results indicate that the methodology is reliable and produces distinct results for the members of the same team. The appreciation of the social competency level is compared to different external sources of assessment, like the qualitative evaluation at the end of the campaign, or the evaluation of the performance of the students during the internship at the industry from the professional advisor. In all cases, the congruence of the data within the margin of confidence attributed to such a topic is very good.

Given the appropriate educational environment, in which the social abilities of the students are put in practice, the method devised produces results that can serve many educational purposes. For instance, to clearly demonstrate what type of behaviors and attitudes we expect from the students, to give them a way to guide them towards these behaviors and attitudes, as well as to provide an early identification of students with a low social competency level. The use of this assessment allows introducing specific exercises addressed towards these low performers; the use of the information collected permits to assemble balanced teams, just to name a few related advantages of this assessment. In summary, the knowledge of the students' social competency level opens a broad range of educational activities, all aiming at fostering the appropriate set of capabilities that would make the future engineer an excellent professional in a global environment or, simply, "Fit for Future".

Acknowledgments

I would like to thank different people who have made this thesis possible. All these people have helped me to develop personally and professionally in the field of teaching and research. Moreover, I honor the Escola Tècnica Superior d'Enginyeria Química for all the resources given to me in order to develop my thesis. Without the participation of the staff, it would not have been possible to carry out this thesis.

Firstly, I would like to thank my supervisor, Dr. Josep Bonet Avalos, who offered me the chance to work with him on this thesis. His scientific knowledge, guidance, support, advice, and our fruitful discussions helped me to focus this work in the best direction. This thesis could not have been accomplished without the financial support of the Premi d'Excel•lència Docent given to Dr. Josep Bonet Avalos from the Universitat Rovira i Virgili. I am grateful to all members of the Molecular Simulation research group. Furthermore, I am especially thankful to Teresa Mármol, a person who, when things become difficult, always simplifies things, while at the same time, caring for the welfare of the whole research group. Moreover, I am very grateful to Maria Serral for her kindness, friendship and support throughout this period. It was a pleasure for me to share certain moments with her, while doing our corresponding thesis.

My sincere gratitude goes to my co-supervisor Dr. Hans J. Witt for his scientific guidance and the constructive discussions about this thesis and for his invitation for us to work together within his company (Witt & Partner) during one week in Germany.

I would like to extend my gratitude to Ulrich Khrüne for having supervised my work during the stage in the Department of Chemical and Biochemical Engineering in Technical University of Denmark, where I felt like I was at home, and for accepting to evaluate my thesis as an external evaluator.

I would also like to thank Dr. Svante Gunnarsson for being the president of the jury and external evaluator of my thesis. Special thanks to Dr. Asier Aranzábal and Dr. Clara Salueña for accepting to be members of the jury.

Finally, I would like to dedicate my thesis to my family. Firstly, my sincere thanks to Cristina for always being there, for all the support throughout the development of this thesis, for her trust in me, and for giving me all her love. Secondly, I am very grateful to my godparents, Joan and Teni, who have advised and helped me during these years to grow up. Thirdly, I would like to thank my grandparents, Paco and Angustias, for all the effort that they went to give me the opportunity to go to the university. Ultimately, thanks to all of them for being part of my life, I will never forget all their affection and love.

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Chapter 1

Introduction

1 Introduction

One of the most significant aspects in the evolution of study programs in Europe, United States, and Asia during the last decades has been the call to provide students with an education in order to be more competitive in today's dynamic global labor market. This education cannot focus on the technical competencies only: it has to involve other qualities beyond the application of these technical skills in a complex environment, to ultimately promote the progress of the entire society. The simultaneous development of social competencies (i.e. interpersonal communication, team work, entrepreneurship or leadership) is the key to excel in the development of proper engineering capabilities in today's organizational environment. It is therefore a logical consequence that professional organizations, accreditation agencies, and national panels promote the development of humanistic abilities in the engineering curricula, which have to grow hand-in-hand with the traditional technical abilities. As an example, in ABET's third criterion *Students Outcomes* [ABET2014], it is stated that the educational program accredited must guarantee *(d) an ability to function on multidisciplinary teams, (f) an understanding of professional and ethical responsibility,* or *(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.* CDIO stresses in its standards similar aspects [CDIO2014]. In the standard 2 (Learning Outcomes), they refer to the CDIO Syllabus, which makes explicit emphasis on (…) *individual students' cognitive and affective development*, (…) *system thinking, creative thinking, critical thinking, and professional ethics*, (…) *focus on individual and group interactions, such as, teamwork, leadership, and communication*. Other organizations, like IChemE [IChemE2014] or ENAEE [ENAEE2014], express similar requirements in their explicit mentioning of the so-called *transferable skills*. To emphasize this paradigm, many engineering curricula contain explicit activities, designed to promote these transversal, transferable, humanistic or simply social competencies in the student. Obviously, traditional teaching methods, centered on the professor's magisterium with passive students listening the lecture, do not create the appropriate environment needed to foster the building of teamwork or leadership and, much

less, initiative and entrepreneurship. Meaningful learning experiences instead, closer to the expected engineering practice, produce the adequate framework [CDIO2014]. There, the students first become aware of the need for development of social competencies; second, they practice these competencies; and, third, they can receive an appropriate assessment of the level of deployment and mastering.

Universities in Spain, traditionally underfinanced, and plagued with other structural limitations, have neither the necessary human resources nor the appreciation to accomplish this task. Nevertheless, they must meet the new demands: the professionalization of the studies to optimize the employability of the future engineers (graduate and master). Hence, the new study programs have to include the traditional technical competency, but, in addition, facilitate the development of the necessary social competencies to make the engineers competitive on a global level. To the contrary, the Escola Tècnica Superior d'Enginyeria Química (ETSEQ) at the Universitat Rovira i Virgili in Tarragona, has a long standing tradition in the building of social competencies in the engineering curricula through the Integrated Project. The Integrated Project is a project-based learning methodology, applied from 1980's ever since, evolving in order to fulfill the requirements of the paradigm [Giralt1994a, Giralt1994b, Giralt1999, Giralt2000, Witt2005]. Nowadays, another step forward is required: we have to evaluate these social competencies, so that the students adapt their behaviors to this paradigm even more effectively.

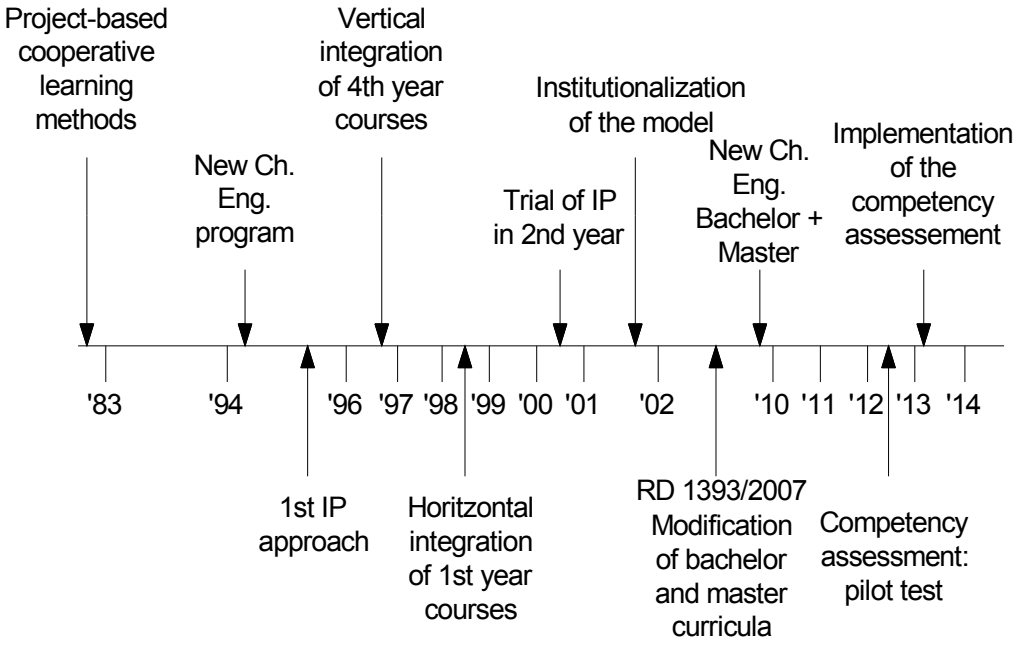

Figure 1. Evolution of the ETSEQ educational model.

The assessment of the social competency level however, represents one of biggest challenges in the transformation towards the educational paradigm, since the object of evaluation is human behavior, instead of knowledge or practice. Unfortunately, little research has been done up to date to develop an adequate assessment of social competencies in engineering education. Especially, if we compare the latter with the experience acquired during the past twenty years in the application of hands-on activities and the recreation of professional contexts during the studies, focusing on the enhancement of professional attitudes as a complement of purely analytical skills. The creation of CDIO and its growth is a vivid example of the latter.

The reason for this imbalance between focus on knowledge vs. behavior is, in our opinion, attributed to the intrinsic difficulty of observation, since social competencies refer to what people do in the context of engineering practice. Therefore, with the purpose of providing an assessment of the students' level in social competencies, one has, in the first place, to create the alluded appropriate environment, where the student immersed in it can show attitudes,

undertake actions, take decisions, etc., related to the practical application of engineering, whereby the social competencies would be naturally deployed in an almost-professional context. Secondly, the procedure has to provide an assessment a) objective, b) individually differentiated even in teamwork, and c) deprived of any psychological diagnosis, which lies beyond the scope of our function as professors. Finally, the assessment has to be accompanied by supporting educational programs, which give the student an opportunity to raise her/his competency level and ultimately increase her/his fitness for the social tissue where she/he shall play her/his role as an engineer.

Furthermore, the assessment of social competencies has additional benefits for the students and for the professors. First of all, the assessment gives importance to each competency itself, especially if the student obtains a competency profile that can be added to her/his portfolio, complementing her/his academic record. Secondly, the assessment of social competencies drives the professors to reflection on how much these competencies are deployed during the educational program and how to improve their character of role models for their students.

In this thesis, we discuss the experiences led during the past few years in the ETSEQ to implement an effective and feasible method to determine the students' social competency level for the five social competencies selected, related to the standards afore mentioned. The methodology described in the thesis is strongly centered on the objective observation of what the students do, captured in a 360º degree survey, ranging over several months of teamwork during an engineering project. We discuss the conceptual basis of the method, the instrument devised, as well as the inherent difficulties of its application. We will demonstrate that the method produces results that discriminate between members of the same team and permits to identify students that require individual help to raise their level of social competencies. The lack of action would hamper the possibility of giving them a chance of a reasonable insertion in the labor market. We hope that the case discussed in this thesis serves as a starting point for future development of enhancements of feasible methods for assessment of social competencies.

Chapter 2

Competencies and their evaluation

2 Competencies and their evaluation

The growing challenges of the global market generate pressure on higher education towards transforming graduates capable of leading and fostering the progress of society. The focus is on developing competencies rather than only on knowledge and practical skills in the students [ABET2014, Spencer1993, McClelland1998, AQU2012].

In this chapter, we introduce how we define *competency* and its role in the context of higher education. Furthermore, we describe the basic problem of assessing the student's level in a given competency, which is the central subject of this thesis.

2.1 Definition of competency

The concept of *competency* stems from the observation of the difference between average performing and outstanding professionals in different jobs. The birth of the concept can be attributed to David C. McClelland [McClelland1973], who published the article *Testing for Competence Rather Than Intelligence* in 1973. In this article, the author indicates how traditional tests, based on academic aptitude and knowledge, are unable to predict the job performance and success in life. It is interesting to read the detailed example of the recruiting of U.S. State Department Foreign Service Information Officers [Spencer1993], as an example where these ideas are demonstrated.

Spencer & Spencer define a competency as [Spencer1993] (sic.):

> *A competency is an underlying characteristic of an individual that is causally related to criterion-referenced effective and/or superior performance in a job or situation.*

Although this definition is neither unique nor probably the best, it indicates that the individuals that excel in their function do not distinguish generally by their knowledge or experience, but rather by other capacities, many of them of social nature. More specifically, Spencer & Spencer define (*sic.*):

- *Underlying characteristic* means that the competency is a fairly deep and enduring part of a person's personality and can predict the behavior in a wide variety of situations and job tasks.
- *Causally related* means that the competency causes or predicts behavior and performance.
- *Criterion-referenced* means that the competency predicts who does something well or poorly, as measured on a specific criterion or standard.

Five types of underlying characteristics of a competency are the following (*sic*.):

- *Motives*. The things a person consistently thinks about or wants that cause action.
- *Traits*. Physical characteristics and consistent responses to situations or information.
- *Self-concept*. A person's attitudes, values, or self-image.
- *Knowledge*. Information a person has in specific content areas.
- *Skill*. The ability to perform a certain physical or mental task.

As we can observe from an iceberg analogy in Figure 2, knowledge and skill types are visible to others. In the hidden part of the iceberg, we would find self-concept, traits, and motive types of competencies, which are related to the personality of the individual in question. Thus, knowledge and skill can in principle be more easily developed to reach a higher level of competency, and, at the same time, more easily evaluated. However, the personality-related competencies are by their own nature more difficult to develop and assess. This distinction will play a crucial role along this thesis.

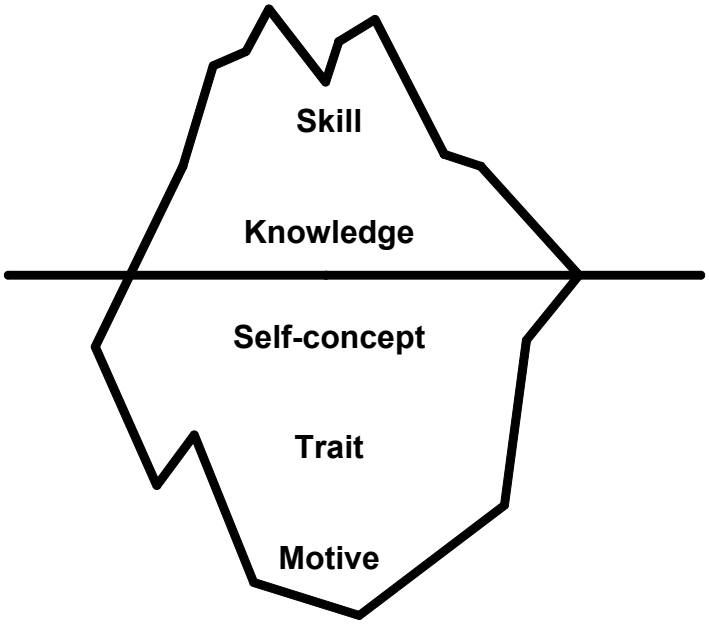

Figure 2. The Iceberg analogy.

A *competency dictionary* is therefore a set of competencies that consistently distinguish individuals with superior performance in a given job or professional context. For example, Spencer & Spencer, after the analysis of *behavioral event interviews*[1] of many professionals of different kinds, proposed the characteristic traits of an outstanding technical professional, as given in Table 1 (cf. Table 13-1 of ref. [Spencer1993]).

Table 1. Generic competency model for technical professionals. Left column is a measure of the relative frequency of the item encountered in behavioral event interviews.

Weight	Competency
6	Achievement orientation
5	Impact and influence
4	Conceptual thinking
4	Analytical thinking
4	Initiative
3	Self-confidence
…	…

[1] We will give details about the behavioral event interview (BEI) in section 2.2.1, *Considerations about the observations, the measure and its objectivity*.

Of particular interest is their remark (sic.)

> *Technical/professionals deal primarily with problems concerning machines (…) rather than with interpersonal processes and problems. Given this focus, it is intriguing that fully one-quarter of the distinguishing characteristics fall into the interpersonal and managerial clusters. The best "hard science" technical/professionals use interpersonal skills and teamwork to accomplish their technical works.*

It is therefore beyond fashion that the social competencies allow to characterize and predict superior performance in a job.

The exact meaning of the words in Table 1 is, however, somewhat vague. Hence, the definition of a competency has to be substantiated with terms about items that we can objectively observe and therefore elaborate on [Wittgenstein1922].

It is common knowledge that a competency profile, namely the ensemble of levels that a person has in a given competency system, is the best predictor of future performance of an individual in the related job. Furthermore, we have illustrated that the social competencies, which are hard to observe, play a crucial role also in technical jobs.

2.2 Evaluation of competencies

After our brief interlude on what we mean by competency, we face the topic of competency assessment. Leaving the definition of the competency dictionary [Spencer1993] constructed in the ETSEQ for the next chapter, in this section we focus on the problem of the knowledge and the measure themselves. Technical competencies have long been evaluated in traditional educational systems. As mentioned in the previous section, one can objectively determine the performance of the students in the capacity of solving a mathematical exercise

or to operate a given unit in a laboratory. The outcome of such an activity is evident to the observer's eyes, and grades can be assigned from this direct observation, within a given scale or framework. Social competencies, instead, refer to people's behavior more than to the outcomes, and their observation is by far more subtle than checking the result of a technical test. Thus, in this section we focus on precisely this problem, namely, the epistemological consequences of the need for the reliable and objective observation of human behavior.

This matter is a subject of debate by itself, since it is not obvious at all that reliable comparisons could be established between individuals, even with regards to the technical skills. It is argued that the definition of a given standard is not enough to compare individual performances, since often the meaning of the words are elusive, the observers have cultural biases, or simply that *qualities, which refer to achievement or performance, are not directly observable or measurable* [Sadler2013]. All these issues have been addressed in our approach, trying to find an eclectic position between the feasibility and the conceptual concerns that plague the debate about the students' competency assessment [Sadler1987].

2.2.1 Considerations about the observations, the measure and its objectivity

In order to develop a methodology to determine the competency level of the individuals (the students enrolled in one of our engineering studies, in our case) with regards to their social competencies, we have adopted a point of view as close as possible to that of modern Physics on the question of the measure [Faye2008], particularly when referred to intrinsically fluctuating variables. This point of view will be more evident within the statement of the postulates below.

On the other hand, from an ethical point of view, we have adopted the position that the measure of the competency level should avoid psychological or moral statements. Professors in the engineering domain are meant neither to deliver

psychological diagnosis nor to make moral judgments of the students, which lay beyond the scope of their function in their educational context.

Therefore, let us propose two fundamental postulates:

Postulate 1. The object accessible to the observer is the so-called *observable*. Hence, for our purposes, the observable is

> *the behavior of an individual in a given moment, in a concrete environment, and exerting a given role related to her/his actual studies (and the future profession).*

Therefore, we can not have access to *what a person is* or to what in psychology is known as *a mental state*, "deep down in the iceberg". We can observe *what a person is doing* as the only indicator of her/his capabilities, particularly with regards to the actions that are proper of individuals with a high standard in a given social competency.

Postulate 2. The measure is a process of comparison. The objectivity of the measure is hence based on the existence of a *standard*, in the first place, which will be the same for all the observers in its application to the evaluated individuals. Secondly, considering that the human behavior depends on the circumstances and the *states of mind* (which exist as facts of the inner individual experience but that are not directly accessible to others), we can consider that the final objective is to determine what the person does *in general*, not in a specific moment, a particular day, or under concrete circumstances. Therefore, to guarantee the objectivity of the assessment of the competency level, it has to be determined from an average of observations obtained by different observers, in different moments, under different circumstances, but always while the individual is exerting its role, to which the standard refers to.

With regards to the educational, ethical and psychological dimension of the knowledge of the student's competency level, as professors, we adopt *cognitive-behavioral* perspective [Schacter2010]:

- Speak about behavior, not about values or feelings
- Evaluate only the behavior
- Educate the behavior through specific actions
- Inspire the values, inspire by example.

Within this *cognitive-behavioral* perspective one acknowledges that there may be behaviors that can not be controlled through rational thought. The procedures to be undertaken are "problem focused" (the “problem” understood as a low competency level) and "action oriented" (meaning that the staff proposes the student specific strategies to help addressing the low competency level) [Rachman1997].

Hence, in agreement with the postulates, we have defined a 360º evaluation system. It means that each individual will be evaluated from different observers, but using the same rubrics as the standard along many situations where the expected behaviors can take place. The methodology is described in section 3.3 *Evaluation procedure.*

To close this subsection, let us consider another methodology, which has been traditionally used to determine the competency profile, namely the *behavioral event interview* (BEI): “The basic principle of the competency approach is that *what the people think or say about their motives or skills is not credible*. Only what they actually *do*, in the most critical incidents they have faced, is to be believed” (sic.) [Spencer1993]. The purpose of the BEI method is to conduct an interview in which the interviewer, behind what people say they do, can find out what they *really* do. This is accomplished by asking people to describe how they actually behaved in specific incidents, including successes and failures [Spencer1993]. This methodology was used in our School as a method to collect data about the development of the competencies of our students in the

subject of fourth year oriented towards the leadership competency development [Özgen2007]. However, BEI has serious limitations:

- The application of this assessment to a large population of about 300 students would require the implication of unavailable human resources in any average institution of high education.

- In order to implement BEI methodology, people with specific formation to drive the interviews and, most important, to interpret appropriately the results obtained are required.

Hence, for the purpose of the assessment intended in this work, this otherwise useful technique when less people are involved, has been discarded.

2.3 The competency model of the ETSEQ

2.3.1 Definition of the ETSEQ's competency dictionary

The competency model developed in our School complies with the *Real Decreto 1393/2007, de 29 de octubre*, together with the *Orden CIN 351/2009, de 9 de febrero*, which provide the framework for the modification of the bachelor and master curricula to the Bologna framework. Moreover, at the Universitat Rovira i Virgili, we also had to take into account the set of so-called *nuclear competencies*, which are related to the capacities of communication, responsibility and professional ethics. In this framework, the ETSEQ has determined a competency dictionary of Table 2 [Avalos2011]:

Table 2. Competency dictionary of the ETSEQ.

Classification	Competency
Technical Competencies	A1. Technical
	A2. Professional
Social Competencies	B1. Human interaction and Versatility
	B2. Facilitative Leadership
	B3. Teamwork
	B4. Active Learning and Responsibility
	B5. Initiative and Innovation
Nuclear Competencies	C1. Communication
	C2. Social

We want to emphasize that these competencies are meaningless as they stand just by themselves.

Each of these competencies is defined through several behavioral descriptors. Ultimately, however, the meaning is bound to the set of observable behaviors associated to it, namely, what outstanding engineering professionals do. The behavioral descriptors corresponding to the competencies given in Table 2 are detailed in Appendix 1. As an example, we put forward:

Table 3. Behavioral descriptors related to the competency B1 Human Interaction & Versatility.

Competency	Descriptors
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.
	1.2 Able to translate thoughts into oral and written communication.
	1.3 Adapts behavior and work method in response to changing conditions.
	1.4 Deals effectively with high workload.
	1.5 Displays resilience.
	1.6 Resolves conflict constructively.

A-type competencies are linked to the technical knowledge, which have been traditionally evaluated in the study programs through objective tests and exams. As far as their evaluation is concerned, we will assume that, when the students pass this kind of subjects, they should have acquired the technical competencies. B- and C-type competencies gather the social competencies that we mentioned before. C-type competencies are the URV nuclear competencies, referred to the command of different languages, the use of ICT's (information and communication technologies), professional ethics, together with the concern about the personal development.

The competency model proposed is oriented towards the performance of our students as future engineers within their jobs in industry and society. With this in mind, we followed the rule that 7 to 9 competencies are required for a given job description [Shippman2000]. More specifically, our competency dictionary is analogous to the competencies listed in the tiers *Workplace* competencies and *Personal effectiveness* competencies of the *Advanced Manufacturing Competency Model* of the Clearinghouse Model [ETA2014]. The scope of the different systems for competency models has been reviewed in ref. [Ennis2008]. Strictly speaking, our competency model should have been constructed following an empirical process of correlating the superior performance of our alumni with indicators of technical capacity and social behavior collected during their studies at the ETSEQ, according to the process described by, for instance, Spencer & Spencer [Spencer1993]. Unfortunately, at present, no data is available, neither about the academic performance of our alumni, different from their academic record, nor about their performance in actual or past jobs. Therefore, we have constructed our competency dictionary based on these generic competency dictionaries, suitable for the profile of engineering students.

2.3.2 Rubrics

From Table 3 we see that behavioral descriptors themselves are too vague and can not constitute the standard of reference satisfying the requirements of Postulates 1 and 2. To construct such a standard of reference of behaviors consistent with the postulates, we have introduced rubrics for each behavioral descriptor, focusing on elementary behaviors. This means, simple behaviors that can easily be recognized, customarily known as *pinpointed behaviors*. Of course, such pinpointed behaviors are defined not only with regards to the competency and the related behavioral descriptor, but in addition they must refer to

- The context: in which environment the observations are meant to be done.
- The function: in which role the person is going to be observed – what is the student expected to do.

As an example, in Table 4 we list the rubrics related to the same competence B1, as in Table 3. The complete list is shown in Table A 1 in Appendix 1.

Table 4. Behavioral descriptors and rubrics for the B1 Human Interaction & Versatility competency, for the role of team member.

Competency	Behavioral descriptors	Pinpointed behaviors
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Expresses clearly her/his ideas and opinions to the others during the group meetings.
		When working with others, listens to other's opinions and makes sure (for example, by asking questions) that she/he understands other's ideas or points of view.
	1.2 Able to translate thoughts into oral and written communication.	The ideas are clearly expressed, either orally or written, either in group meetings, interviews, reports or other circumstances related to the work.
	1.3 Adapts behavior and work method in response to changing conditions.	In the case of failure of a procedure, erroneous result during the work, in the case of the need of a change, looks for a new solution or approach, adapts to the new conditions.

		When she/he has to change the role inside the group, when new tasks are addressed, adapts easily and effectively to the new role or to the new task.
	1.4 Deals effectively with high workload.	When tasks are distributed or workload is increased, she/he does not complain and positively faces the new workload.
		In the moments of high workload expresses or encourages to a positive attitude to the other team members.
	1.5 Displays resilience.	Keeps the compromises acquired in the framework of the team and the context of the ongoing project.
	1.6 Resolves conflict constructively.	In the case of a conflict, mediates and collaborates effectively in the solution of the conflict.

In section 3, *The ETSEQ educational model and the process of evaluation*, we provide details of the context in which the process of evaluation has been implemented.

Due to the link of the elementary behaviors to the function, the list that defines the standard for the leader has differences with respect to that of the team member, as shown in Table 5. The complete list is given in Table A 2 in Appendix 1.

Table 5. Behavioral descriptors and rubrics for the B1 Human Interaction & Versatility competency, for the role of leader.

Competency	Behavioral descriptors	Pinpointed behaviors
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Looks for the best in team members irrespective of own personal opinion and judgment.
		Expresses her/himself clearly, taking care of being understood (for example, expressing ideas, giving feedback, addressing tasks to the team).
		Builds effective relationships in and outside the team to improve performance.
		Updates team members and stakeholders on progress.

	1.2 Able to translate thoughts into oral and written communication.	Clearly explains to the team members what her/his expectations are.
	1.3 Adapts behavior and work method in response to changing conditions.	Increases her/his leadership in front of difficulties and challenges.
		Encourages others to contribute and come forward with own ideas.
		In the moments of high workload encourages taking a positive attitude to the team members by acting as a role model.
	1.4 Deals effectively with high workload.	When the workload is high she/he reviews the work plan with the team and resets priorities.
	1.5 Displays resilience.	Is able to cope with set backs and disappointments while focusing on moving the team forward.
	1.6 Resolves conflict constructively.	In the case of a conflict, she/he faces the situation by finding a solution with win-win scenarios.
		Understand conflict resolution methods and applies them effectively.

We can not establish rubrics able to distinguish between the expected performances of a student from first, second, and third year. Therefore, in view of the harsh postulates to which we adhere to, we shall use the same rubrics across the studies for each function. Instead, we will monitor the progress in a given competency through the increase in level across the studies, indicating that the behaviors given in the rubrics are observed more often or with more intensity as the student progresses course by course.

From an epistemological point of view, the list of the rubrics is what defines the meaning of the behavioral descriptors and, hence, of the competencies. That is, if competencies can not be related to observables, in the sense of Postulate 1, they bare no meaning. Thus, our position parallels also the essential characteristics of a competency as being *criterion referenced*, as mentioned in section 2.1, *Definition of competency* , according to ref. [Spencer1993].

Chapter 3

The ETSEQ educational model and the process of evaluation

3 The ETSEQ educational model and the process of evaluation

In this chapter, we explain the context in which the competency evaluation process takes place, as well as the actual procedure that we implemented to harvest the data used in this thesis.

3.1 The Integrated Project

The ETSEQ in Tarragona started a re-engineering process more than a decade ago. Due to visionary and committed staff of professors [Giralt1994a, Giralt1994b, Giralt1999, Giralt2000], a unique educational model was developed and implemented, whereby students acquire social competencies along with management skills practicing these skill-sets in an *integrated project* (IP). This IP approach assures the acquisition and application of these competencies, along with gaining firsthand experience about implementation issues. This unique model claims to be a strategic response to the challenges posed by globalization. In ref. [Witt2005] the authors give a description of both, the conceptual background as well as the practical implementation of the educational model in our School. The reader is addressed to this reference for a complete view.

The IP is a genuinely hands-on activity in which the students labor in teams on a pre-assigned project to produce a given outcome during an academic year. The IP outcome can be a technical report, written and/or defended through a presentation, a prototype, or any other product, issued as a result of the team's activity. The IP outcome contains a technical solution to a given problem. We use the expression IP outcome in this work to refer primarily to this technical solution.

In the first course, the IP is centered on balances of matter and energy. Each team assembled with first year students of the bachelor degrees of chemical engineering (GEQ) and food engineering (GEA) is led by one fourth year student of these degrees. This team leader is following the elective subject *Team Leadership Practice* (PLE). The students of the latter receive specific formation on leadership. They integrate the acquired knowledge in this and other disciplines, practicing within the framework of the IP in the first course. Second year students address an IP on product and process design (GEQ), or heat and freezing treatments in food processing (GEA). The leader and team members, instead, belong to the same course in this case. Third year students face an IP on process simulation and optimization (GEQ), or quality management in food industries (GEA), with the same structure as in the second year. The teams in second and third year courses, although they have a leader, she/he is more a *primus inter pares* that acts also as a team member. Schematically, the structure of the studies is given in Figure 3. The specific formation received in social competencies by the students of the courses involved is given in section 3.2, *Roles and teams*.

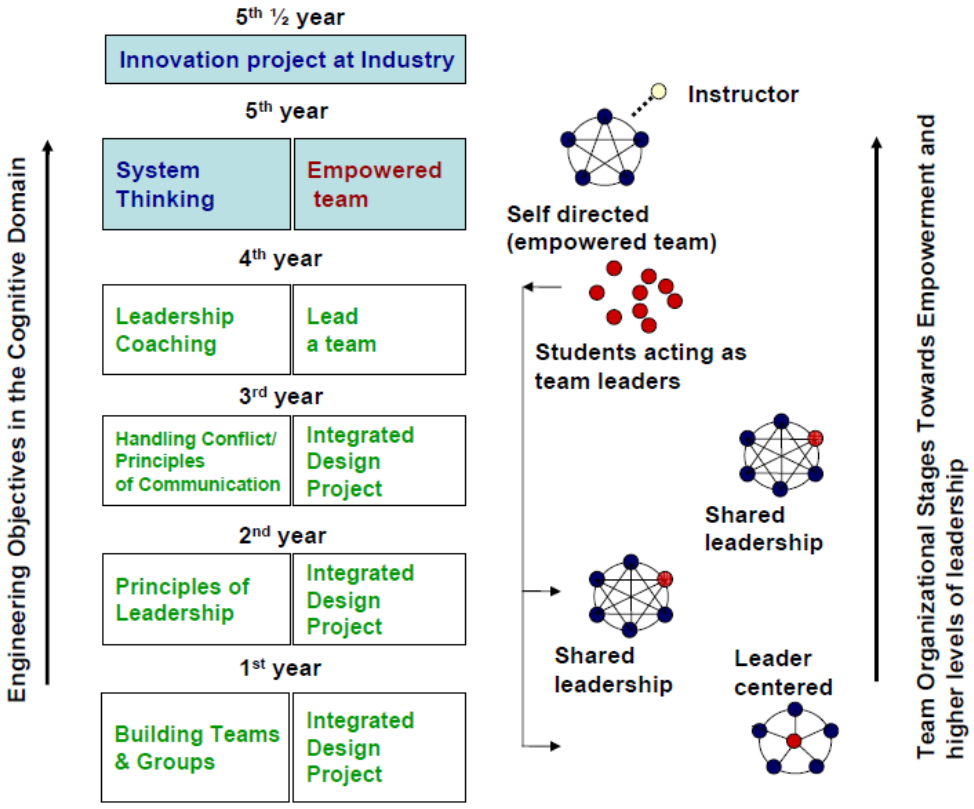

Figure 3. Structure of the Integrated Project system in the bachelor and master in chemical engineering. White boxes stand for the bachelor degree while light blue boxes correspond to the master. Inside the boxes, the specific training in social competencies is indicated, associated to the type of hands-on activity. On the right, we indicate the kind of organization of the teams.

The hands-on activities carried out in the IP's comply with the basic principle of the CDIO organization, to which the School belongs [CDIO2014]:

> *Beginning engineers should be able to Conceive--Design--Implement--Operate complex value-added engineering products, processes, and systems in modern team-based environments. They should be able to participate in engineering processes, contribute to the development of engineering products, and do so while working to professional standards in any organization. This is the essence of the engineering profession.*

Hands-on activities are central to the implementation and operation steps of the CDIO principle. Although traditionally chemical engineering is not the most suitable discipline to let the students build their own prototypes, as dangerous chemicals may be involved, laboratory open problems, involving unit operations or more complex processes, permit to cover this part. Integrated projects cover not only the conception and design parts, but are also a suitable framework to embed the students into the alluded team-based environments, to participate in engineering processes and product development, as well as to face professional standards.

The integrated project environment, therefore, recreates inside the university a professional environment close to the modern practice of engineering. In such an environment, the student is compelled to deploy all the competencies, both technical and social, practice them, and demonstrate the behaviors that can be compared with the rubrics for the evaluation.

3.2 Roles and teams

As we mentioned in the previous subsection, in our IP's we differentiate two roles regarding the main functions that the students play in the IP. These roles are

- team member
- leader

The team members are expected to fulfill the tasks related to the engineering practice, be it technical, information seeking, report writing, public presentations, actively participate in the elaboration of the *team charter*[2], properly behave as a member of a structured team, etc.

[2] The Team Charter is a dynamic document (can change along the time) that provides the scope of the project, the objectives, the team, the stakeholders, the roles and its responsibilities, the planning of the project, the strategies to take decisions, etc. This document is made by the team as a whole.

The leader, while acting as such, is expected to manage the team, which implies plan and assign the tasks, fix the intermediate deliverables and milestones, look after the appropriate climate within the team, including anticipating conflicts, and constructively resolving them, if the latter remains inside mild forms of discrepancies within the team, among others.

Specific formation is planned every year to cover the need of our students, concerning the social competencies, regardless of their roles. This formation corresponds to modules/courses given in Table 6.

Table 6. Table of compulsory and elective modules and courses supporting the educational model. The modules are customarily delivered in a single session at the beginning of the course. The PLE course instead corresponds to a full elective subject involving the fourth year students.

Year	Module/Course	Hours
First	Building Teams & Groups	4
	Teamwork	4
Second	Principles of Leadership I	4
Third	Principles of Leadership II	2
	Principles of Communication	4
	Handling Conflicts	2
Fourth	Team Leadership Practice (PLE)	60
	Team Leadership	4
	Coaching	4

The development of the IP's requires the staff of professors participating in a specific course to play themselves assigned roles. These roles are:

- Expert: the professors of the subjects of the course, not necessarily the subject of the IP itself, will act as experts about their subjects. The students can address questions related to the IP, concerning their area of expertise, to them.

- Client: the same professors will act as clients when reviewing the IP outcome, particularly with regards to their area of expertise. One or two professors, with a chemical engineering profile, review the IP outcome as a whole in the context of the engineering discipline to which it refers (chemical engineering or food engineering).

- Tutors: each team has a tutor assigned from the staff. Tutors are meant to conduct supervision of the technical work to detect possible substantial flaws at an early stage, suggesting information seeking, and, overall, looking after the proper development of the IP. This is a position of trust towards the team and, therefore, she/he does not participate in the evaluation of her/his supervised team. Tutors of one team do participate in the evaluation of other teams as experts.

- PLE professors (fourth year): since the students enrolled in PLE are leaders of teams of the first course, PLE professors act as *coaches* of their assigned leaders, helping them in the matter of leadership and in the process of the practical implementation.

The teams are not randomly built, neither is their composition left at the students' hands. For the first year students, lacking any record about the social competency profile of the freshmen, students of PLE build balanced teams by collecting information from a questionnaire that they have been asked to construct and apply, in light of empowerment with the mentoring of the PLE professors. This questionnaire usually contains queries about the students performance in some basic subjects (like mathematics, physics, chemistry, etc.), together with questions on actions and attitudes under hypothetical situations that can help them to assign a certain social profile, related to the expected roles in a team. These questions have the same nature as the Belbin test [Belbin], for example, which we used in the past.

The coordinator assembles the teams of second and third year based on the information from the competency profile gathered in the IP of the previous year. The method that we are describing in this work is intended to be used in the future to build balanced and similarly competitive teams, in a systematic way, for the second and third course, based on the information gathered during the first course.

3.3 Evaluation procedure

Postulate 2 demands that repeated observations of the behavior of an individual acting in her/his role during the IP are to be done by different observers. To fulfill this requirement, but also to deepen the empowerment of the students, their sense of responsibility, as well as to let them know about our educational expectations (through the standard), we leave a significant part of the observation process in their hands.

In this subsection, we explain the evaluation procedure of the competency assessment for the IP of the first course. For the second and third courses, the procedure is analogous.

3.3.1 Forms

We have defined two different forms, each containing the questionnaire related to the two roles to be evaluated, in which the different observations are recorded. We use the form F1 to evaluate the team members and the form F2 to evaluate the team leader. These forms share the five social competencies of the model, as well as the behavioral descriptors, but they carry the elementary behaviors associated to the specific function they play (37 for the team members and 50 for the leaders; see Table A 1 and Table A 2 in Appendix 1 for the details). The forms carry the name of the observer (Alice), the name of the person evaluated (Bob), the date of the evaluation as well as the observation itself. In our initial implementation, we had to create as many files as couples of

Alices and Bobs existed, including self-evaluation. This was necessary to assure confidentiality. At the end of the evaluation process, all files regarding the same individual, Bob, are merged into one single file.

To clarify the method, we utilize a case study corresponding to a team in the first course led by a student of PLE of the 4th. Hence, the leader has to create a form F2 for the self-evaluation and, simultaneously, as many F1 forms as team members compose the team. Her/his professor of PLE has to create another form F2 to evaluate the leader. Finally, each team member has to create a form F2 to evaluate the leader, an F1 for auto-evaluation, and as many additional F1s as other team members are in the team. All F1 forms are shared with the leader, while each F2 form is shared with the PLE professor. Consequently, at the end of the semester/course, the professor of PLE has to create a unique form F2 for the leader, compiling the evaluations done by her/himself, by the team members, as well as by the leader in her/his self-evaluation. Similarly, for each team member the leader gathers all her/his F1 forms and constructs the final unique form for each team member.

The pinpointed behaviors in each form have to be evaluated by the observer using a scale with three values: 0, 1, 2, depending on whether the elementary behavior has been observed *seldom* (0), *sometimes* (1), or *often* (2), denoting frequency, or *low* (0), *medium* (1) of *high* (2), if it denotes intensity. In case that the circumstances are not appropriate for the observation of a specific behavior, the observer leaves the evaluation of the item *blank*. At the end of the course, the average of the observations will provide, for each competency, a grade, which is finally scaled up to a range between 0 and 10. The student then receives a qualitative interpretation of her/his competency profile. We will come back to this point in section 4.2, *Typical results*.

3.3.2 Participants

Once the standard per role has been established, along with the form of the questionnaire to be used, we had to decide on the frequency for the evaluation. We have established:

- Professor of PLE: she/he has to evaluate the leader twice a month using the form F2 that contains the leader's rubrics.

- Leader: she/he has to use the form F1 to evaluate individually her/his team members once a week, equally using the form F2 for the self-evaluation with the same periodicity.

- Team member: she/he has to use the form F1 to evaluate her/his teammates (cross-evaluation), perform the self-evaluation once a week, and also has to use the form F2 to evaluate the leader once a week. To reduce the evaluation "burden", however, the competencies to be evaluated are distributed among the team members, so that each team member evaluates all the other team members only with respect to one single competency (maybe two, depending on the size of the team), while another team member evaluates the leader. These roles rotate among the team members according to a calendar that the leader establishes at the beginning of the season.

This system helps us to define a 360º evaluation process, according to postulate 2. Then, each individual is evaluated from different observers but using the same rubrics, i.e., with the same standard. For example, in the designed system, the leader will be evaluated from her/his tutor, from her/his team members, and by her/himself. In the case of a team member, she/he will be evaluated from the leader, self-evaluated, and from her/his teammates. In the last campaign, the weight of each evaluation was determined by the frequency, corresponding to the same weight (1/3) for self-, teammates and

leader observers. The competency profile of each student is calculated as an average at the end of the course.

3.3.3 Shared and confidential information

Assuming that five team members and one leader compose a team, they have to handle 36 forms, as we indicated in subsection 3.3.1, *Forms*. These forms contain personal and sensitive information about the individuals, and we have to guarantee that the data is treated confidential and stored safely.

With this purpose in mind, and without any computer-assisted system devised to this end, we had to find a system to share the forms between the individuals of the team. Google Drive allowed us to store the information and keep it accessible from everywhere (in the cloud and not in personal computers to avoid information dissemination), share the specific forms with leaders, professors or tutors. Each student had to create or use her/his own Google Drive space and manage the forms there, including the sharing option. In Table 7 we show the sharing network:

Table 7. Shared information between the participants. We have to read from left to right; for example, team members has to share their forms F1 with the leader and their form F2 with the professor of PLE.

Who shares	With the leader	With the prof. of PLE or tutor
Team members	Form F1	Form F2
Leader	-	Form F1

3.4 Pilot test

To check the feasibility of the procedure, we conducted a pilot test during the 2nd semester of the course 2012-2013, involving one team of the integrated project (GEQ/GEA) of the first year (the leader was a student of the fourth year),

one team of the fourth year (involving several students of PLE of the GEQ), and one team of the second year (GEA). We involved a total of 17 students, 3 of them as leaders, and the rest as team members. The procedure allowed us to collect 70 observations related to the leader role and 232 observations for the of team member role; that is, 20 observations/leader and 15 observations/team member.

Using the data collected, we performed an analysis to validate the methodology and the rubrics, i.e. the instrument. The objective was to determine whether this is a) statistically significant, b) consistent with the ability to identify the superior performance, c) discriminating between individuals, and d) feasible in our educational model. The typical results of the pilot test will not be discussed here because we will center our attention on the 2013-14 campaign, where the procedure was scaled up to all courses of GEQ and GEA. The details of the pilot test can be found in ref. [Suñe2014]. However, important lessons were learned during this pilot test, which have been integrated in our work.

Workload: The participants measured the time spent in completing the corresponding questionnaires after the weekly meeting. We found that each team member spent about 10 minutes to evaluate 2 competencies of her/his remaining 4-5 teammates, together with the self-evaluation. The leader spent about 20 minutes to evaluate the 5 competencies of her/his 5-6 team members and to complete the self-evaluation. In turn, the professors of PLE spent 5 minutes to evaluate one leader over the 5 competencies.

Internal consistency: The internal consistency of the instrument was determined calculating the Cronbach's α from the data. The results were satisfactory. A more detailed analysis from the data of the course 2013-14 is given in 4.2, *Typical results*. Furthermore, we compared the predictions obtained from the instrument with the subjective appreciation of the observers at the end of the process (qualitative evaluation), on the same set of 5 social competencies directly on a scale from 0 to 10. We wanted to know the correlation between the competency level obtained from data collected and the subjective impression of the observers at the end of the integrated project. In the case of fourth year

students, we compared the result of the evaluation through the instrument with the evaluation of the supervisors of these students during the internship at a company, that is, with a direct professional experience. To make the comparison, we set corresponding equivalences (see details in Appendix 5) of the items evaluated in the internship and the competencies for our model, to have a rough estimate of the competency level within our framework of 5 social competencies.

Thus, at the end of the pilot test we concluded that:

- The estimations of the workload to complete the evaluation questionnaire indicate that the methodology demands an affordable burden and, therefore, the procedure is feasible in practice.

- The comparison with the qualitative evaluation indicates that the predictions of the model are qualitatively similar to these at the end of the pilot test. It is particularly remarkable that the results from the industry supervisors and from the instrument are in line.

- Our instrument is statistically sound and allows us to identify competency levels that manifest in quasi-professional situations. Moreover, the instrument allows us to discriminate among individuals of the same team.

Chapter 4

Implementation

4 Implementation

4.1 Scale up

The data presented correspond to the observations carried out in the first and second course of the bachelor studies of Chemical Engineering at the ETSEQ. Data was collected every week from the beginning of November 2013 through the end of May 2014. The first course involved 99 students, 26 of which belonging to the studies of Food Engineering, sharing the complete first course with the GEQ. The second course involved 57 students, exclusively from GEQ. The number of fourth year students (GEQ), participating in the IP as leaders, was 20. We have centered our attention to the IP of the first course, led by a fourth year student, and the second course, which is led by one of the members of the team. Although the second and third year of GEA and the third year of GEQ participate in the evaluation process, data collected has not been considered in this study, but will be considered elsewhere.

The participants of the first course were enrolled in the subject *Fundamentals of Process Engineering* (FEP). The integrated project of this course takes place within this subject. Together with the activities related to the IP, a theoretical content, regarding the application of balances of matter and energy in typical chemical or food engineering processes, was also delivered and separately evaluated. In parallel with the collection of observations on the behavior of the students, we also use the grading obtained in this theoretical part as an estimate of the technical competency level of each student. The teams were composed of four-to-five team members led by a fourth year student. Each team member received a total of about 60 observations of the behavior during the academic year, while the leaders received about 35 observations.

In the second course, the integrated project is embedded in the subject *Chemical Products and Processes* (PPQ). This subject also included a theoretical content that is separately evaluated, also used as an estimator of the

technical competency level of the students. The 8 teams taking part in the PPQ integrated project were composed each by six-to-seven team members plus a leader. The period of data collection was the same as in the first course and followed the same pattern, except that the periodicity was two weeks. Roughly, each student received about 30 observations during the academic year. The evaluation of the leaders followed the same scheme as for the first year, but replacing the PLE tutors now with the own PPQ tutors of the second year. The number of evaluations for the leaders was about the same as for the team members.

The commitment of both, students and staff, was very high. The level of social competencies obtained from the evaluation had impact on the final mark of the first and second course students, but not on the mark of the PLE students of fourth year. In practice, we only had to discard data of two teams of the first course due to lack of consistency in the data reported after the campaign by two leaders. In the concluding section we will return to this point and the intrinsic difficulty to maintain a system that demands not only a certain degree of commitment of a large number of students, but mainly commitment of a substantial number of staff members with varied professional and personal interests.

4.2 Typical results

At the end of the campaign, we have a file for each student containing every single evaluation (the mentioned unique file in Microsoft Excel format). By means of a Matlab program, we read the data and perform the averages $\overline{x^{\alpha}}$ for each pinpointed behavior α, as well as the unbiased variance S^{α} of each measure, according to

$$\overline{x^{\alpha}} \equiv \frac{1}{N}\sum_{i=1}^{N} x_i^{\alpha} \qquad 1$$

where *i* indexes the *i*th- student in a population of a total of *N*, and

$$S^{\alpha 2} \equiv \frac{1}{N-1}\sum_{i=1}^{N}\left(x_i^{\alpha} - \overline{x^{\alpha}}\right)^2 \qquad 2$$

The competency level *X* of a given competency described by δ pinpointed behaviors $\left(x^{\alpha}, x^{\beta}, \cdots, x^{\delta}\right)$ is then given by

$$\overline{X} = \frac{\left(\overline{x^{\alpha}} + \overline{x^{\beta}} + \cdots + \overline{x^{\delta}}\right)}{\delta} \qquad 3$$

Finally, an interval of confidence of 66% in the estimation of *X* is given by the range $X = \overline{X} \pm \Delta X$ where

$$\Delta X^2 = \sum_{\alpha=1}^{\delta}\frac{S^{\alpha 2}}{N^{\alpha}} \qquad 4$$

N^{α} being the number of observations of each α pinpointed behavior for the given individual.

Since data are in a range of 0-2, we finally rescale the values to a range of 0-10 for the ease of the interpretation, defining it as the traditional scale in our national system. The results were recorded back into each student's file. A detailed typical example of the data recorded and analyzed is given in Appendix 2.

The competency level X obtained by the students is in average around 7, within an interval of confidence of about 1.5 per competency. This result indicates the baseline of the social competency level of the participants, as seen through the instrument. On the other hand, the confidence interval is rather large, as to be expected from the observation of the fluctuating human behavior. Hence, students with a competency level around 7 can be considered as average performers, while levels above this average are significant indicators of an outstanding performer. Therefore, to enforce the discrimination between the performances of the students, while dealing with the concern of the intrinsic uncertainty of the measure, we have further adopted a qualitative assessment, according to the scale given in Table 8.

Table 8. Qualitative scale of the social competency level.

Range	Qualitative level
0-4	Needs serious improvement
4-6	Needs improvement
6-8.25	Average performance
8.25-10	Superior performance

To set the limits of each range, we have defined an exponential scale in form of $X_{\exp} = \exp\left(X^{*}\ln(11)/10\right)\text{-}1$, where $X_{\exp}$ is the *stretched level*, which also lies within the range of 0-10. The stretched level $X_{\exp}$ emphasizes the differences of the mean and superior performers, allowing for a better discrimination. The limits of the regions of the qualitative level are chosen by first dividing $X_{\exp}$ into three regions of equal size, and then dividing the lower region into two more equal sub regions. The boundaries obtained in this way are transferred back to the standard X. We have adopted this criterion of division in significant regions according to the stretched scale but keeping the linear scale to maintain the customary impression about the grades. The numerical data on the competency level, the standard deviation, together with the qualitative assessment just described, is transferred into an individual PDF document that is ultimately provided to the students for consideration.

Table 9. Four examples of the competency level (Level) with the corresponding confidence interval (dev.), determined according to eq. (4). TM 1 and TM 3 are arbitrary students of the 1st course. TM 2 and TM 4 correspond to students of the 2nd course. Colors indicate the qualitative assessment given to the students: green and yellow correspond to superior and average performance, respectively, while red and maroon stand for needs improvement and needs serious improvement, correspondingly.

		TM 1		TM 2		TM 3		TM 4	
		Level	dev.	Level	dev.	Level	dev.	Level	dev.
B1	Human Interaction & Versatility	9.2	1.0	8.3	1.3	6.8	2.5	4.6	3.5
B2	Facilitative Leadership	9.4	0.4	8.1	1.2	5.7	2.5	3.8	3.2
B3	Teamwork	9.2	0.9	9.3	1.0	6.5	1.9	3.4	3.1
B4	Active Learning & Responsibility	9.7	0.6	8.0	1.5	7.4	2.1	3.4	3.5
B5	Initiative & Innovation	9.2	1.0	8.0	1.3	7.4	2.5	3.8	3.1

In Table 9 we have selected four characteristic results corresponding to a superior performer (TM 1), an average-high performer (TM 2), an average performer that has to improve her/his leadership abilities (TM 3), and a very poor performer (TM 4, the worst performer of the whole campaign, in fact). In view of the results, several comments are appropriate. In the first place, we observe that the method is able to discriminate the performance of the students not only among them, but also between the different competencies of the same student. Secondly, it is interesting to note, that the deviation ΔX increases as the competency level decreases. This can be attributed to different possible causes but, particularly, to the following: from the enquiries individually done at the end of the campaign on the students' qualitative appreciation of the different competency levels of the other team mates and leader, we can infer that a certain degree of a good-will in the judgments dominates the day-to-day student's evaluation. Such a good-will is gradually gone near the end of the course if the behavior of the student is perceived by leader and team mates as affecting negatively the climate in the team or the IP outcome. As a consequence, we have a major dispersion of the evaluations of students with lower profile. The consequences of this fact will be discussed in subsection 5.1, *Conclusions*.

To analyze the teams themselves as entities, we show below the obtained results for two teams of the 1st year and two teams of the 2nd year. We have added the grades of the theoretical part of the subject, whereby the integrated project took place as an individual indicator of the technical competencies of each student. In the case of the second year students, we have also included the grades of FEP, of the previous year, since this information was available and is potentially relevant. Furthermore, as an indicator of the team performance (IP outcome), we have added the grade obtained by the team in the final report of the integrated project, which contains the development of the technical solution proposed by the team to the problem addressed. None of these indicators of technical competencies or IP outcome, therefore, contain a direct numerical influence of the levels obtained for the social competencies of the team members.

As an example, in Table 10 and Table 11 we have chosen a characteristic team with a superior and average performance of the 1st course, respectively. In Table 12 and Table 13 we show the results of a team with an average-high performance and average with an asymmetry, both of the 2nd course, respectively. As before, we observe that the procedure is able to discriminate performance between individuals, even belonging to the same team. In all cases, we observe that the grades obtained in the technical exams are quite de-correlated from the average competency profile of each student. We will see this fact also reflected in the analysis of the population later on. However, we can already see that students with a high competency profile have in general better grades than students whose overall competency profile is low. Moreover, we can also guess that the final IP outcome is better in the teams with high profile than in those of low profile, although we find that the differences are not too significant. The analysis of team performance in light of the observed combination of social competency profiles with technical competencies of team members, will be studied elsewhere.

Table 10. Example of the first year team that has the best IP outcome.

		Team Members				Leader
		TM 1	TM 2	TM 3	TM 4	
B1	Human Interaction & Versatility	9.2	9.4	9.7	9.4	9.4
B2	Facilitative Leadership	9.3	9.6	9.6	9.0	8.7
B3	Teamwork	9.5	9.6	9.7	9.4	9.4
B4	Active Learning & Responsibility	8.7	9.6	8.9	9.0	9.2
B5	Initiative & Innovation	9.0	9.7	9.6	9.5	8.2
A	Technical competency	3.1	9.7	2.6	4.8	
	Outcome of the IP	8.5				

The team described in Table 10 was, with regards to the IP outcome, the best of the 1st year. Remarkably, the social competency level was very high for all the team members including the leader. However, their technical competencies were very poor, except for one outstanding member. Notice that the leader does not directly participate in the elaboration of the technical part of the work, unlike the second course, where the leader also participates in the work as a team member.

Table 11. Example of a first year team with an average IP outcome as well as the competency profile of the whole team but with a very poor level of technical competencies.

		Team Members				Leader
		TM 1	TM 2	TM 3	TM 4	
B1	Human Interaction & Versatility	7.77	7.88	7.79	7.06	6.77
B2	Facilitative Leadership	6.29	7.18	6.97	6.51	7.38
B3	Teamwork	6.83	7.10	7.47	6.43	7.02
B4	Active Learning & Responsibility	6.70	7.08	7.34	6.89	6.96
B5	Initiative & Innovation	7.14	7.12	7.02	6.01	6.61
A	Technical competency	0.70	2.40	5.10	1.50	
	Outcome of the IP	6.01				

The evaluation from the team in Table 11 indicates that the whole team has an average competency level. In this case, TM3 is the only one with technical competency above 5, whereby the other members have a low level of technical competency. Nevertheless, the IP outcome of the team is acceptable.

We conducted the same type of analysis with the teams of the second course.

Table 12. The table shows an example of a superior team with the competency level of all members (team members and leader). This team belongs to the 2nd course of GEQ.

		Team Members						Leader
		TM 1	TM 2	TM 3	TM 4	TM 5	TM 6	
B1	Human interaction and versatility	8.82	8.97	8.98	8.44	8.67	8.71	9.00
B2	Facilitative leadership	8.50	9.12	8.94	8.30	8.89	8.41	8.87
B3	Team work	8.63	9.02	9.15	8.32	8.56	8.19	9.11
B4	Responsibility and active learning	8.21	8.83	8.58	8.66	8.05	8.51	9.17
B5	Initiative and innovation	8.20	8.90	8.64	8.41	8.37	8.71	8.89
A	Technical competency (PPQ 2013-14)	6.00	7.10	7.20	6.60	3.50	6.90	6.50
	Technical competency (FEP 2012-13)	5.08	8.37	7.18	5.47	0.65	7.82	8.67
	Outcome of the IP	8.00						

Table 12 is an example of a team with superior performance, in which all team members and the leader have very good results regarding their competency level. However, we can observe a negative evolution of the technical competency from the first course to the second course in some cases. In the opposite way, it is remarkable that the IP outcome is high.

Table 13. Example of a second year team. The table shows an example of an average team with the competency level of all members (team members and leader). This team belongs to the 2nd course of GEQ.

		Team Members						Leader
		TM 1	TM 2	TM 3	TM 4	TM 5	TM 6	
B1	Human Interaction & Versatility	6.7	5.1	8.5	7.8	8.0	6.4	8.4
B2	Facilitative Leadership	6.4	4.6	8.0	7.5	8.6	6.2	8.2
B3	Teamwork	6.8	4.3	8.5	8.2	8.9	5.9	7.4
B4	Active Learning & Responsibility	6.3	4.7	7.3	7.5	8.3	6.6	7.6
B5	Initiative & Innovation	6.6	4.9	7.9	7.6	8.6	6.5	7.8
A	Technical competency (PPQ 2013-14)	6.8	6.6	6.8	7.0	7.2	5.8	8.4
	Technical competency (FEP 2012-13)	5.0	5.1	4.7	4.8	7.6	8.1	10.0
	Outcome of the IP	7.7						

In Table 13 we have selected an average team of the 2nd course, but with asymmetric profile among the members. In this case, it is noteworthy that one team member has a very low social competency profile.

As seen in Table 13 as an example, we can find some teams with a member rated low by her/his team members, including the leader, in a consistent way. Surprisingly, we have no indication of conflict occurring within the team, handling the situation well and eventually managing to obtain a more than decent outcome. This individual is clearly a candidate to receive help from the staff to increase her/his competency level. Furthermore, it is interesting to see a strong consistency between technical competencies of the 1st (FEP) and 2nd (PPQ) subjects, much more than the example selected in Table 13 may suggest. General data indicate that second year students perform better in the technical part than they did during the first course.

4.2.1 Validation

To assess the significant character of the instrument we have devised three checks across the information that is available.

In the first place, we will study the correlation matrix. Let us denote the deviation of an instance from the mean as

$$\Delta x_i^{\alpha} \equiv x_i^{\alpha} - \overline{x^{\alpha}} \qquad 5$$

The elements $r_{x^{\alpha}y^{\beta}}$ of the correlation matrix r are defined as

$$r_{x^{\alpha}y^{\beta}} \equiv \frac{\overline{\Delta x^{\alpha} \Delta y^{\beta}}}{\sqrt{\overline{\left(\Delta x^{\alpha}\right)^2}\ \overline{\left(\Delta y^{\beta}\right)^2}}} \qquad 6$$

where x^{α} and y^{β} are two given pinpointed behaviors related to competency *X* and *Y*, respectively. The averages (denoted by the bars over the symbols) are

defined as in eq. (1). By construction, the diagonal elements are all 1, which implies that the trace of the matrix is equal to the total number of items considered. In Appendix 3 we show some relevant elements of the correlation matrix for the team members of the first course. From the Table A 4 in this appendix, we see that there are positively correlated items that may indicate redundancies in the pinpointed behaviors listed. An example of this fact from the aforementioned competency *B1* is the pair

1. Expresses clearly her/his ideas and opinions to the others during the group meetings
3. The ideas are clearly expressed, either orally or written, either in group meetings, interviews, reports or other circumstances related to the work

whose correlation coefficient is 0.84 (over a maximum of 1). Although we intended that an attitude, shown during the team meetings (1), is differentiated from the capacity for formal expression on written documents (3), the fact is that these two items are very similar. Keeping redundant items in the questionnaire biases the evaluation of the competency level and, therefore, should be eliminated. However, the following pair

5. When he/she has to change the role inside the team, when new tasks are addressed, adapts easily and effectively to the new role or to the new task.
8. Keeps the compromises acquired in the framework of the team and the context of the ongoing project.

has also a high correlation factor of 0.78 but, in this case, the correlation stems from a characteristic of the population itself. The two pinpointed behaviors 5 and 8 are clearly describing two different aspects and, therefore, are significant despite the high correlation obtained. We have found positive correlation values above 0.7 in 15 pairs, which corresponds to the 2.25% of all possible pairs in the team member correlation matrix for the first course. The analysis of them reveals that, except for the first pair indicated above, these correlations correspond, from our point of view, to characteristic traits of the individuals of the population. In the case of the leader, the total number of correlated pairs

over 0.7 is 67 out of the 50x(50-1)/2= 1225 possible pairs, which is the 5.47% of the total. The analysis reveals again that the correlations are to be attributed to traits of the personality of the individuals. We will see in the subsection 4.2.2, *Analysis of the population*, the role played by these correlated items, that is, which information is hidden underneath the correlations.

The second check is done through the Cronbach's α coefficient, which gives a measure of the internal consistency of the test [Cronbach1951]. Formally, for any given *X* one computes in our case

$$\alpha_X \equiv \frac{\delta}{\delta - 1}\left(1 - \frac{\sum_{\alpha=1}^{\delta} S^{\alpha 2}}{S_X^2}\right) \qquad 7$$

We have calculated this parameter for the five social competencies for both roles of team member and leader. The result is given in Table 14, where we have also included the overall Cronbach's α of the test.

Table 14. Cronbach's α of the different competencies evaluated for both the team members and the leader. Values have been obtained from data of the first course.

	Team member	**Leader**
α B1	0.90	0.89
α B2	0.90	0.83
α B3	0.86	0.86
α B4	0.86	0.81
α B5	0.86	0.68
α overall	0.97	0.96

According to the customary interpretation of this parameter [Brennan2011] in the context of creating tests to measure constructs (psychometric tests) in populations, the values obtained indicate that the internal consistency of the test is very good. The poorest consistency is found in the evaluation of the *Initiative* and *Innovation* competency for the leaders, although its value still permits us to

consider the test as fairly good for this competency. The results for the second course are similar.

The third and last consistency check is the comparison between the competency levels obtained from the instrument and the estimate of those from the supervisors at the industry during the internship of the fourth year students, which have been the leaders of the first year students during the course analyzed. In Appendix 4 we show the 9 leaders with available data on the internship. Several comments are appropriate. First, we obtain differences between the estimation of the competency level from the internship and the values obtained from the instrument. From the 9 students analyzed, with 9x5=45 cases in total, the deviations of 30 instances are in the range $\Delta = \pm 1$ or less. Moreover, 10 out of the remaining 15 indicate an overestimation of the competency level by the instrument in 2 points. Taking into account that a) the supervisor's evaluation corresponds to the qualitative observation of one single person, b) that we have estimated the competency level from the supervisor's questionnaire for internship, whose questions are significantly different from those in our questionnaire, c) that there is a large uncertainty in the estimation of the competency level, and that d) the correspondence is defined rather subjectively, we consider, that the instrument produces a qualitative, yet reliable picture of the competency profile of the students. In Figure 4 we show the different evaluations for two randomly selected examples. One can verify that the profiles are rather coincident although numerical absolute differences exist.

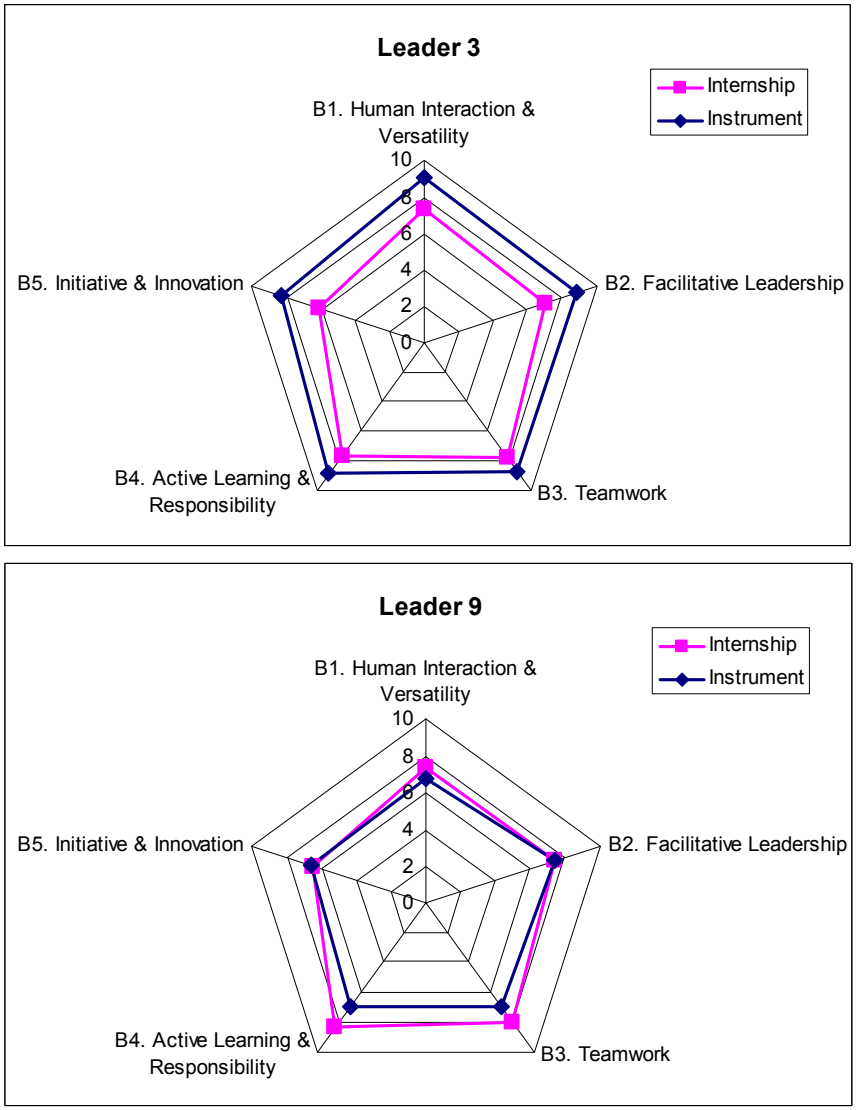

Figure 4. Comparison between the competency level profiles of two leaders of teams of first course students. In the case of Leader 3, the level is slightly overestimated, while the Leader 9 shows a very good agreement between the estimation of the instrument and the internship.

4.2.2 Analysis of the population

The Principal Component Analysis (PCA) is a tool to determine the principal directions of variation of a given collection of data [Jolliffe1986]. To simplify the analysis, we have considered here the reduced 6×6 correlation matrix, in the

sense of eq. (6), whose elements r_{XY} involve the correlation between the five social competencies *B1-B5* plus the grade in the theoretical part related to the technical competency *A*. Since by construction the correlation matrix has unity diagonal elements, the trace is 6. The ratio between a given eigenvalue *E* to the trace indicates the relative weight of the associated eigenvector *V* within the population.

Table 15. Eigenvalues and eigenvectors of the principal component analysis of the competencies of team members of the first course.

Eigenvalues	**0.10**	**0.12**	**0.14**	**0.27**	**0.80**	**4.58**
Eigenvectors						
B1	0.63	-0.56	-0.28	-0.10	0.04	0.45
B2	-0.60	-0.44	0.07	0.49	0.09	0.44
B3	0.33	0.61	0.01	0.57	0.09	0.43
B4	0.01	0.06	0.77	-0.44	0.13	0.43
B5	-0.35	0.32	-0.57	-0.48	0.18	0.43
A	-0.06	0.06	0.00	-0.06	-0.97	0.23

In Table 15 we can observe that the main direction of variation of the students' competency profile is given by the vector V_1, associated to the eigenvector $E_1 = 4.58$ that represents the 76% of the trace. Moreover, the components of the associated eigenvector are $V_1 = (0.45, 0.44, 0.43, 0.43, 0.43, 0.23)$ are all positive and very close to each other except for the last, i.e. technical competency, which is lower. Interpreting the eigenvector as the competency profile of a individual, V_1 would correspond to an overall balanced profile, with no large differences between competency levels for the same person. Hence, the competency profile of the individuals is overall rather flat. The first three eigenvalues gather 94% of the trace. A graphical representation is given the Figure 5.

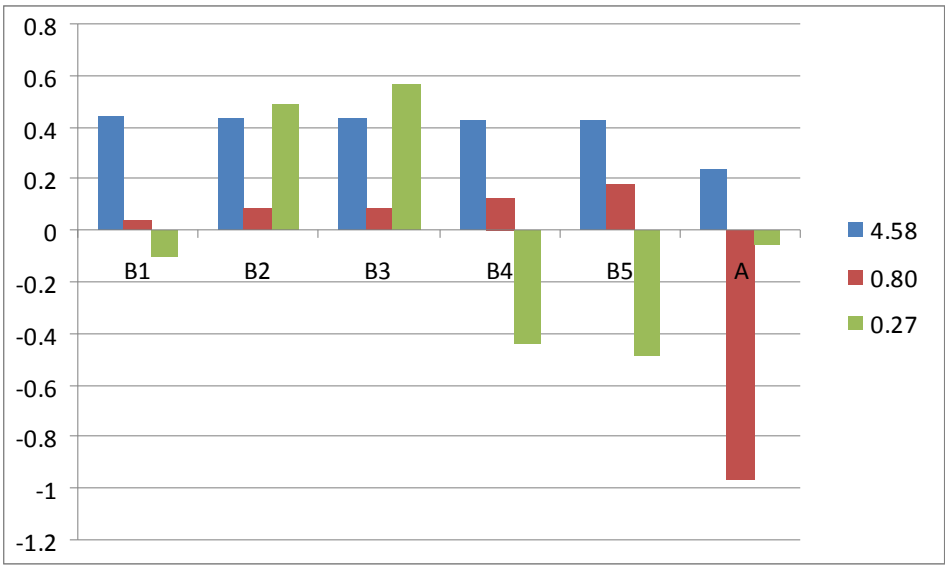

Figure 5. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the team members of the 1st course.

With regards to the second eigenvector $E_2 = 0.80$, we observe that this almost exclusively refers to the technical performance. This fact indicates what we have already mentioned, i.e., that the technical capacity is practically independent of the social competency profile. Finally, the third eigenvector $E_3 = 0.27$ shows a profile where the *Facilitative Leadership* and *Teamwork* competencies vary in an opposite way to the *Active Learning & Responsibility* (*B4*) and *Initiative & Innovation* (*B5*). Remarkably in this profile, *Human Interaction & Versatility* (*B1*) and Technical Competency (*A*) do not play a relevant role. The overall sign of the eigenvector is immaterial since it refers to the correlation matrix and, therefore, only the relative sign of the components of the different competencies for the same eigenvector contains relevant information. We have repeated the PCA analysis excluding the technical competency A. In this analysis, the second eigenvector in Figure 5 disappears, but the first and third eigenvectors become first and second, without significant variation. This is again a clear indication that, in the population of the first year, students' social and technical competencies are not correlated and can be separately considered.

The analysis of the population of the 2nd year students yields the same profiles, which is again an indication of the internal consistency of the instrument, as well as the homogeneity of the population.

Since the functions of the leader of the team are different, in Figure 6 we show the three first eigenvectors and eigenvalues of the PCA analysis for the leaders of first year. With respect to the team members, the first eigenvector carries the same qualitative information. Since the technical competency is not considered for these leaders, we compare the second eigenvector with the third of the case of the team members. Again, the main differences between the most important secondary component and the first lay in the opposite tendency between *B1* and *B2,* with respect to *B4* and *B5*, although here *B4* is less relevant. The analysis of the leaders of 2nd course show interesting differences with regards to the previously studied case. In particular, the main eigenvector is $V_1 = (0.48, 0.50, 0.46, 0.52, -0.17)$. This eigenvector is similar to the corresponding of one for team members of 1st and 2nd course and leaders of teams of the 1st course (students of 4th course), except for the fact that the *B5* component has a different sign from the other components. Clearly, the initiative of these inexperienced leaders is below the expectations of their team members. Notice that the evaluation of the *B5* for leaders coincides with the lowest Cronbach's α, and hence the questionnaire has less consistency for this particular competency.

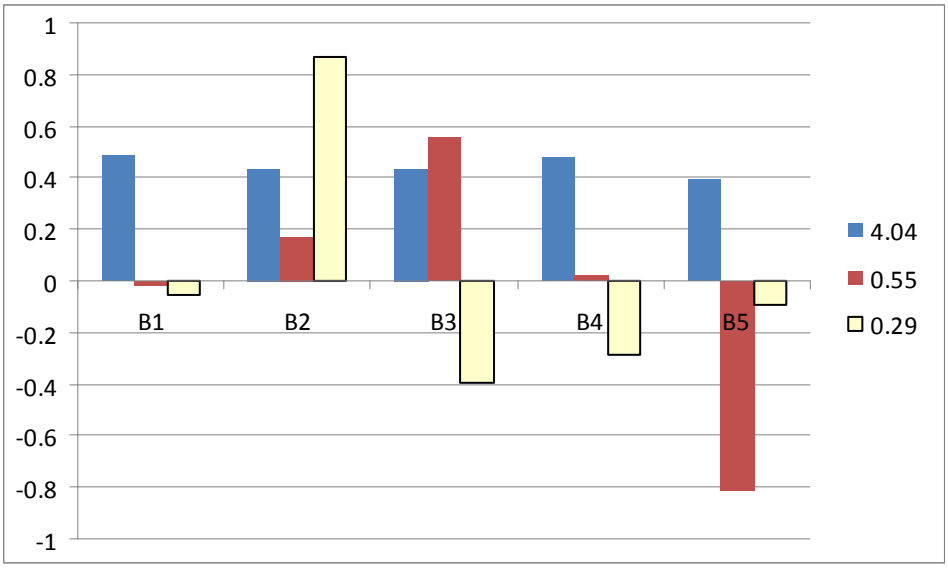

Figure 6. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the leaders of teams of the 1st course (students of the 4th course).

4.3 Discussion

We have seen in Table 9-Table 13 that the instrument described in this thesis is able to provide a reliable estimate of the students' competency profile. However, despite the significant amount of data collected for each individual, the confidence interval is of the order of the mean for the low performers. Therefore, with such a degree of uncertainty in studying human behavior, the data should be handled with extreme care. There are two pitfalls: on one hand, the information should strictly be taken as confidential with the unique concern of the student involved and her/his tutor while, on the other, data should be carefully interpreted and delivered in a soft format using, for instance, qualitative indicators as given in Table 9. However, we think that the identification of students, who consistently show a low competency profile, is one of the advantages of the evaluation procedure that we present, since we expect that the result of the assessment can act as a catalyst for a personal transformation of the student involved. On the other hand, the early identification of individuals

with a low competency profile provides the opportunity to design and apply specific correcting actions to improve the students' capacity [Bandura1977].

Furthermore, accurate information of the competency profile of the students after the first year can help the staff in assembling teams in the second and further courses. With this, these teams possess then an adequate balance between their members, so that the team's *a priori* possibilities of producing an outstanding IP outcome are therefore enhanced. When revising the overall data collected about the teams at the end of the season, we realized, that some teams had very low chances *a priori* of reaching a high grade in the integrated project, because the competency profile and the technical capacity of its members were low overall. Increasing the probabilities of success in the integrated project, due to balanced competencies distributed among teams, must be a subject of concern for the staff.

The frequent data collection can have additional advantages to be exploited in the future. For instance, an early estimate of the competency profile after the first semester can be a leading indicator of the existence of future conflict inside the teams since, for instance, the variation in the cross evaluations between team members can be used as a predictor [Rovira2013]. With this knowledge available, the staff can intervene before the conflict arises, and manage the personal relations between team members accordingly, all aiming at driving towards a successful outcome of the IP. The identification of patterns in the students' cross evaluation could also be used as an indicator of cheating or unethical behavior inside the teams, something that, in the absence of this data, would go unnoticed by the staff.

The PCA of the correlation matrix has shown us that the main competency profile is very homogeneous with regards to the five social competencies analyzed. This indicates that the evaluations cast an image of individuals that have overall high, average, or low level of competencies, without significant imbalances between them. This trait of the population explains the high correlation between items that *a priori* refer to completely distinct behaviors, as we have already commented. Hence, with the objective of gathering team

members for a new team, the social competency profile could be described by one parameter, i.e. the projection of each individual competency profile onto the eigenvector V_1, as a good approximation. More interesting is the third eigenvector, which shows a general tendency of the population to display low capacities of active learning and initiative, embedded in competencies *B4* and *B5*, as compared to overall acceptable levels of leadership and teamwork (*B2* and *B3*, respectively). This tendency is attributed to the fact that a strong emphasis is placed on teamwork and leadership across our curriculum, and much less on personal long-life learning, initiative and innovation abilities. Moreover, in the actual design of the integrated project, it is difficult to create situations whereby students have to consistently display behaviors associated to these *B4* and *B5* competencies. With no doubt, this should be a subject for future research and reflection.

To end this section, let us say a few words on team dynamics. As it has been already pointed out, the knowledge of the students' competency profile could be used to build balanced teams, particularly after the first year. We have performed a preliminary analysis on the impact of the students' competency profiles of a given team on the outcome of the integrated project. Since the structure of the teams of the first and the second year are significantly different, we analyze them separately.

In Figure 7 we show the correlation of every competency for each member of the first course team, including the fourth course leader, with the final IP outcome. In this analysis, we have only considered the first four team members of each team to do the statistics, for simplicity, although a few teams have five team members. To perform such statistics, the team members have been ordered with respect to the technical competency in such a way that the one with the best FEP grade (competency A) within the team is team member 1, and so on. The leader is always the last. Data suggest that all competencies of all team members and leader positively contribute to the IP outcome, as it should be expected. Moreover, the performance is strongly related to the first two team members having overall high competencies. With regards to the technical competency A, the correlation with 1A is the highest, followed by the

2A. The correlation between 4A and 3A is significantly lower. Furthermore, we can clearly see that the initiative and innovation and, to a lesser degree, the active learning and responsibility competencies, namely B5 and B4, are rather determinant, at least when they are present in the two first team members. The latter is rather surprising since intuitively we had always expected that technical (A) and teamwork (B3) were the most relevant competencies for the outcome of the IP. Furthermore, it is interesting to notice that competencies related to human interaction and versatility, as well as facilitative leadership (B1 and B2, respectively), in the leader, have high impact on the final outcome. Therefore, our analysis suggests that the characteristics of a successful team are:

i. To have two team members with high technical competency and, at the same time, high competency level in active learning and responsibility and initiative and innovation (B4 and B5 respectively).
ii. The leader shows high level of human interaction and versatility (B1) and, to a lesser degree, is able to lead well the team (B2).

It is also remarkable that the competency profile of the fourth team member has also a positive impact in the final outcome. Particularly, what is most noticeable is the correlation of the outcome with the teamwork competency (B3) of this member. The effect of the social competencies of the team members with lower A competency in the outcome of the IP is a subject that deserves future investigation.

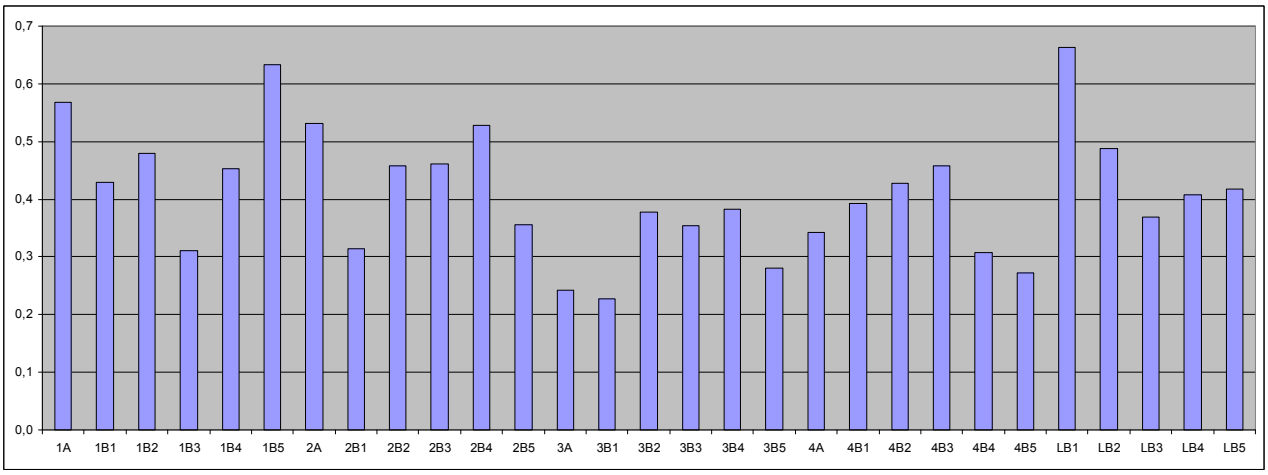

Figure 7. Correlation between the IP outcome and the competencies (technical and social) of the team members and leader of the teams in the first course. In the abscissa we find listed the competencies, using the first character to label the team member (from 1 to 4) and the leader (L). The subsequent characters stand for the specific competency.

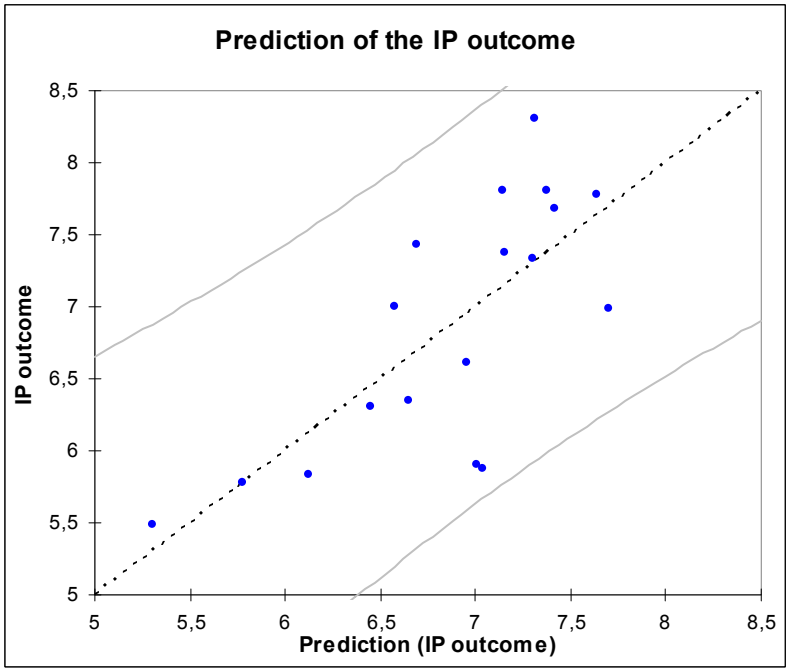

Figure 8. Prediction of the IP outcome of the first course taking into account the grades of the IP. The solid lines determine the limits of a confidence of 95%.

In Figure 8 we can see a linear estimation of the IP outcome obtained from the regression formula

$$IP\_outcome = 2.564 + 0.181 \times 2A + 0.411 \times LB1 \qquad 8$$

The regression is obtained by using the statistical package of the XLSTAT, in which the stepwise method is included in its linear regression model. The program chooses the relevant variables by adding the variable with the largest contribution to the model, using the criterion of the Student's t statistic, which defines the so-called "Probability of entry". If the probability associated with the next variable is lower or higher than the statistic, this variable will be removed or added, respectively. We have chosen the "Probability of entry" to be 0.1, and the best estimate relates the IP outcome to the technical performance of the second team member and the human interaction and versatility competency of the leader. This result goes along the lines of the interpretation made by inspection of Figure 7, commented above. However, one should realize that the relationship between the outcome and the students' competencies may be not linear, and the results of the regression have to be taken only qualitatively. The predictability of eq. (8) should be tested with the analysis of future data.

For the second year students, the analysis is different. First of all, we have to mention that, in this case, we have considered the student playing the role leader merely as a team member, due to her/his role is dual in the second year. We have verified that the highest impact of this student was under the role of team member more than of the leader. Such distinction is reflected in the ordering of the students within the team prior to the statistical treatment.

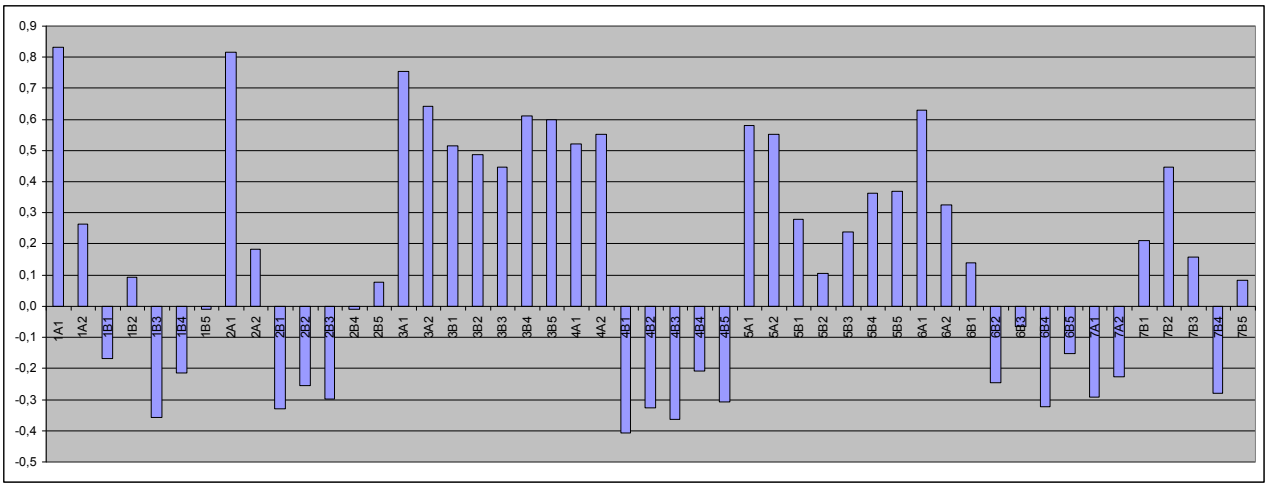

Figure 9. Correlation between the IP outcome and the competencies (technical and social) of the members of the teams involved in the second course. The first character indicates the team member (from 1 to 7, since the role of leader has not been taken into consideration in the classification). The other characters indicate the competency. Here, however, we have also included the grades of FEP (A1) and PPQ (A2) as indicators of the technical competency. The B's have the usual meaning given along this thesis.

In Figure 9, we can observe that not all the competencies analyzed have a positive contribution. The analysis of the second year, with larger teams and lower number of the latter than in the first year, is not significant enough. Consequently, the results are scattered. It would be counterintuitive that a high competency profile contributes negatively to the IP outcome. In the future, with more data available, we expect to refine the correlations in the second course and draw sounder conclusions. At present, data suggests that the technical competencies of the two first members of the team are again very important with regards to the IP outcome. Particularly, the competency A1, related with FEP, is more relevant than A2, related with PPQ. It seems, hence, that FEP (remember that FEP is a subject of the first course, followed by these students the year before) stresses the technical capacities of the students more than PPQ. We have also done the analysis ordering the team members using PPQ grades, but the results using FEP predict the outcome more accurately.

A first estimate of a linear regression of the data yields the equation

$$\begin{aligned} IP\_outcome = {} & 6.313 + 0.990 \times 1A1 - 1.011 \times 1A2 - 0.201 \times 5B2 + \\ & + 0.034 \times 6A2 + 0.141 \times 7B4 \end{aligned} \qquad 9$$

We obtained this linear estimation as in the case of the first year students, here using a "Probability of entry" of 0.05. We have further eliminated a contribution whose coefficient was of the order to 10^{-4}. Notice that in eq. (9) the independent term is quite high, and that there are negative coefficients. These two facts suggest that eq. (9) is practically meaningless, along the lines of the presence of negative correlations in Figure 9. Obviously, the availability of more data can produce more significant results. To obtain a significant regression, we have used a more stringent "Probability of entry" of 0.01, which yield the expression

$$IP\_outcome = 2.771 + 0.515 \times 1A1 \qquad 10$$

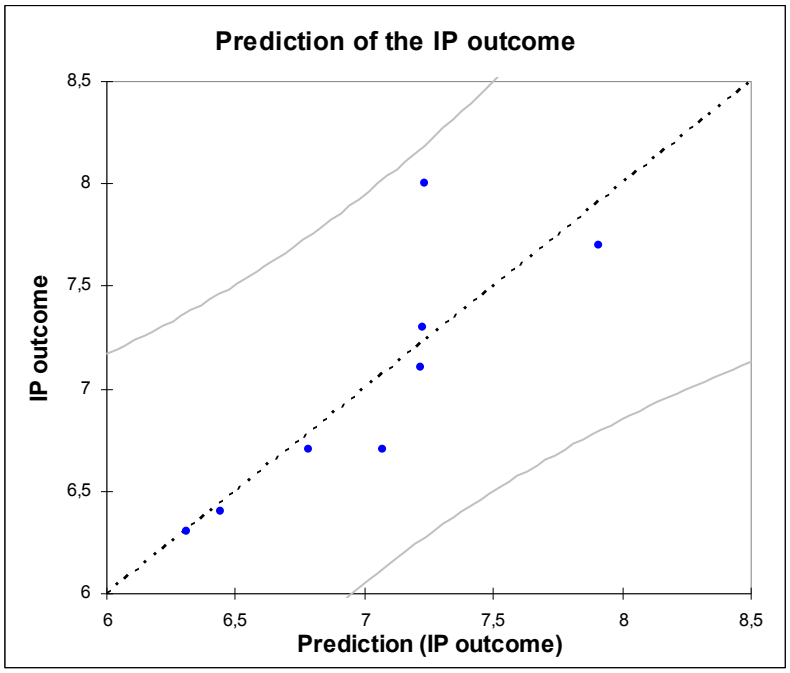

Figure 10. Prediction of the IP outcome of the second course taking into account the grades of the IP. The solid lines determine the limits of a confidence of 95%.

In Figure 10 we show the predicted and measured values of the IP outcome, according to this eq. (10). Here it is clear that the most relevant parameter is again the technical competency of the first team member (A1). To infer the role of other team members' capacities in the IP outcome, new data should be collected. Furthermore, in future analyses the results of non-linear regressions should be explored.

Chapter 5

Conclusions and perspectives

5 Conclusions and perspectives

5.1 Conclusions

According to the results, we can confirm that our instrument is statistically significant and allows us to identify competency levels displayed in quasi-professional situations. Moreover, the instrument provides the ability to discriminate competency levels in different competencies of one individual, but also discriminating performance of the individuals within the same team. The consolidation of the instrument should allow analyses in the long term (say, 5 to 10 years), involving the evolution of the students along the studies, but also along the professional evolution of the graduates in their work life. Particularly relevant will be the correlation between the professional performance and the data on behavior collected during the educational curriculum.

The instrument also delivers qualitative information of the students' behavior during the activities related to the integrated project. This information by itself may play a catalytic effect because, when being put in the hands of the students, acts as a mirror returning an image of themselves, as seen through the eyes of the others. This portrait is an image "colored" by the glass of the instrument, is true, but still is reminiscent of what the student has been doing all over the course. We have seen that the daily use of the rubrics to evaluate other teammates has had an impact on the behavior of the observer (a team member or leader). It is for the first time that the students have a clear picture of what we expect from them, where before only vague statements on teamwork, leadership, or innovation were available. We expect that the improvement of the actual model will end up producing a methodology able to transform our students into better, socially aware, and more competent professionals.

The most important drawback of the methodology is the management of the data in the hands of a large number of actors. Attributed to this is the inconvenience of the treatment of large amounts of data during the campaign.

Handling the evaluation in the way we have done requires a lot of effort from all the participants, be it students, tutors or course coordinators, all who have to do several additional actions, apart from the pure assignment of values in the questionnaire. Requirements like confidentiality are difficult to keep. Moreover, data treatment requires gathering the data collected about one person into a formatted file, enabling subsequent numerical treatment. Also, making sure that formats were not changed during the process, so that standardized analysis programs could be used, has been rather challenging.

However, none of these actions require, in fact, the supervision of a human, but can easily be addressed by a computer-aided system. In such a system, the questionnaire would be presented to the evaluators, and the data, automatically stored. Additionally, data can internally and automatically be worked on. Hence, with the application of such a system, the only concern left is that the observers code the observations into the questionnaire at the required time.

It has also been argued during the campaign that the number of pinpointed behaviors was too large, particularly for the evaluation of leaders (50 items), and that the range of values was too restrictive for a fine appreciation, even considered too harsh for some of them. For future campaigns, we propose to evaluate the behavioral descriptors of each competency on a scale from 0 to 5, instead of each pinpointed behavior in a range from 0 to 2. The description of the elementary behaviors will remain, however, in the questionnaire to give precise content to the descriptor. This action reduces the total number of items to be evaluated down to 22 for both, leaders and team members. We also expect that a broader scale 0-5 may help the observers to be more differentiating, although we lose the simplicity of the direct observation of something that either occurs or does not. In any case, both actions have the same purpose: simplify, systematize, and lighten the process in order to guarantee its long-term application and commitment from all participants involved.

As already stated in the postulates, we think that the anonymous and repeated observations guarantee the objective appreciation of the students' performance

in many senses. For example, it makes the internal arrangements between students to cheat hardly possible. Dishonest behavior can be better detected because data is consistent over the whole period of the campaign. We have not yet fully determined the way these properties can be detected, but it is certainly a subject for future work.

Another important point is the fact that a lot of research still needs to be done to maximize the relevancy of the information. As said, we have observed, for example, that students have a tendency to be indulgent with disruptive behaviors of their teammates at the beginning of the course, while they become more stringent by the end of the course. This can be due to their natural reaction after experiencing the effects of "hitchhikers" or disruptive teammates in the daily interaction and on the final IP outcome. Therefore, a system of weighted evaluations would tend to limit the bias introduced by such a good-spirited judgment and may produce a more precise evaluation of the competency profile. However, weighted evaluations have to be based on a long-term analysis of empirical data to support it.

This knowledge is useful for the students since they are confronted to what the others see in them, in the context of the IP: γνωθι σεαυτόν, *know thyself*. This knowledge triggers by itself behavioral changes in the students by two mechanisms. Firstly, the exposure to the rubrics, when acting as evaluators, causes behavioral changes by imitation of actions suggested by the standard. Secondly, the assessment puts the students face-to-face with what the others see of them. If they do not fancy the image returned by this "mirror", they will have an incentive to change. On the other hand, the existence of such objective knowledge about the students introduces a new educational necessity in the staff, namely, to help our students to improve their competency level. In this sense, during the past campaign we already initiated exercises to improve the competency level of the few students with particular low competency level. It will require substantial effort before a complete suite of efficient corrective actions and exercises is available in light of the cognitive-behavioral context, whose efficacy to ameliorate the competency profile, their self-efficacy [Bandura1977], is consolidated.

5.2 Perspectives

Considering the results obtained, the lessons learned in the pilot test, and the scale up experience, the ETSEQ has developed and implemented specific software to manage the questionnaires and treat the data automatically for the course 2014-2015. This software will be timely accessible for all the observers, who participate in the evaluation of the social competencies through a computer with an internet connection or from their own smart phone. At the same time, this software permits to calculate automatically the competency level profile of each student at the end of the course, as well as to produce the PDF files to be delivered to the students for their information. This framework is indispensable to deal with a large number of participants (over 500 individuals in the ETSEQ, including all the students of all the courses of bachelor studies).

From the data collected, it will be interesting to empirically determine what are the predictive indicators of the alluded *superior performance* of our graduates, when in the labor market. The early knowledge of the competency level of the students opens the possibility of constructing educational strategies that would help reaching an acceptable competency level at the end of the studies. In addition, we can devise such educational strategies to foster an improvement of the competency level, particularly for the individuals with a significant low profile. The effect of this education will be visible across the four years of the bachelor studies, thanks to the assessment system. These strategies could be introduced in the Tutorial Action Plan (PAT).

The availability of the data opens a new field of investigation towards defining the proper descriptors for interpersonal relationships, to trace the intra- and inter-team networks. In this sense, one can establish the relations between the networks created and their evolution with regards to the IP outcome and the individuals in their academic performance. Moreover, one can analyze the predictive capacity of the procedure to foresee the collective dynamics of the teams, to improve team performance, facilitating conflict resolution, variation of the team strategy and foster team's strengths [Katz2004], all of that aiming at

making more competitive teams and better professional individuals in the long run. Social network theory addresses the problem of the origin of social order from the individual activity, that is, the reasons that may explain how autonomous individuals can combine to create enduring, functioning societies [Borgatti2009]. The investigation would be centered on the identification of social regularities in the team performances, beyond the intentions of the individuals, but as a result of the structure of the social environments in which they are embedded. The analysis of the data on the progress and evolution of the teams, as seen by the participants as well as the external observers, will help us to identify the relevant descriptors of the so-called dyadic relations and to extract the structural characteristics of the succeeding teams as compared to the less successful ones. Hence, the central question is what structural aspects in the social network in one team, or between different teams, may condition the fate of their performance in the Integrated Project, and the personal outcome in the learning process of the subjects.

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7 List of publications and awards

7.1 List of publications

- Suñé, F.J. & Bonet Avalos, J. (2012). Avaluació de competències socials a l'ensenyament d'Enginyeria Química. Published in "VII CIDUI: The University: a institution of society", *Proceedings CIDUI 2012*, ISBN 978-84-695-4073-2, Barcelona, July 2014.

- Suñé, F.J., Witt, H.J., & Bonet Avalos, J. (2014). Nous resultats sobre l'avaluació de competències socials a Enginyeria Química. Published in "VIII CIDUI: Flexible training models: a response to the currents needs", ISBN (to appear January 2015), *Proceedings CIDUI 2014*, Tarragona, July 2014.

- Suñé, F.J. & Bonet Avalos, J. (2014). Evaluation of the social competencies in engineering education. Published in "10th International CDIO Conference", *Proceedings CDIO 2014*, ISBN 978-84-697-2147-6, Barcelona, June 2014.

- Suñé, F.J., Witt, H.J., & Bonet Avalos, J. (***accepted***). New results on the evaluation of social competencies in Chemical Engineering. *Journal of Technology and Science Education*, Barcelona.

- Suñé, F.J. & Bonet Avalos, J. (***in preparation***). Evaluation of Social Competences in the studies of Chemical Engineering.

7.2 Awards

- 1st ACUP-CIDUI Special Mention for the best paper presentation at the 8th International Conference on University Teaching and Innovation, Tarragona, July 2014.

Appendices

Appendix 1. Rubrics[3,4]

Table A 1. Team member's rubrics

Competency	Descriptors	Pinpointed Behaviors
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Expresses clearly her/his ideas and opinions to the others during the group meetings.
		When working with others, listens to other's opinions and makes sure (for example, by asking questions) that he understand other's ideas or points of view.
	1.2 Able to translate thoughts into oral and written communication.	The ideas are clearly expressed, either orally or written, either in group meetings, interviews, reports or other circumstances related to the work
	1.3 Adapts behavior and work method in response to changing conditions.	In the case of a failure of a procedure, erroneous result during the work, in the case of the need of a change, looks for a new solution or approach, adapts to the new conditions
		When he/she has to change the role inside the group, when new tasks are addressed, adapts easily and effectively to the new role or to the new task.

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1.4 Deals effectively with high workload.	When tasks are distributed or workload is increased, does not complain and positively faces the new workload.
	In the moments of high workload expresses or encourages to a positive attitude to the other team members.
1.5 Displays resilience.	Keeps the compromises acquired in the framework of the team and the context of the ongoing project.
1.6 Resolves conflict constructively.	In the case of a conflict, mediates and collaborates effectively in the solution of the conflict.

Table A 2. Leader's rubrics

Competency	Descriptors	Pinpointed Behaviors
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Looks for the best in team members irrespective of own personal opinion and judgment.
		Expresses her/himself clearly, taking care of being understood (for example, expressing ideas, giving feedback, addressing tasks to the team).
		Builds effective relationships in and outside the team to improve performance.
		Updates team members and stakeholders on progress.
	1.2 Able to translate thoughts into oral and written communication.	Clearly explains to the team members what her/his expectations are.
	1.3 Adapts behavior and work method in response to changing conditions.	Increases her/his leadership in front of difficulties and challenges.
		Encourages others to contribute and come forward with own ideas.
		In the moments of high workload encourages taking a positive attitude to the team members by acting as a role model.
	1.4 Deals effectively with high workload.	When the workload is high she/he reviews the work plan with the team and resets priorities.
	1.5 Displays resilience.	Is able to cope with set backs and disappointments while focusing on moving the team forward.
	1.6 Resolves conflict constructively.	In the case of a conflict, she/he faces the situation by finding a solution with win-win scenarios.
		Understand conflict resolution methods and applies them effectively.

Appendix 2. Example of the analytic data collected for a given student

Table A 3. Analytic data collected of the B1 competency for a given student

Competency	Descriptors	Pinpointed Behaviors	Average	Deviation	Competency Grade (aver)	Competency deviation	Qualitative estimation
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Expresses clearly her/his ideas and opinions to the others during the group meetings.	1.72	0.46	9.25	1.46	9.40
		When working with others, listens to other's opinions and makes sure (for example, by asking questions) that he understand other's ideas or points of view.	1.83	0.38			
	1.2 Able to translate thoughts into oral and written communication.	The ideas are clearly expressed, either orally or written, either in group meetings, interviews, reports or other circumstances related to the work	1.83	0.38			
	1.3 Adapts behavior and work method in response to changing conditions.	In the case of a failure of a procedure, erroneous result during the work, in the case of the need of a change, looks for a new solution or approach, adapts to the new conditions.	1.83	0.38			
		When he/she has to change the role inside the group, when new tasks are addressed, adapts easily and effectively to the new role or to the new task.	1.89	0.32			
	1.4 Deals effectively with high workload.	When tasks are distributed or workload is increased, does not complain and positively faces the new workload.	1.94	0.24			

Appendix 2. Example of the analytic data collected for a given student

		In the moments of high workload expresses or encourages to a positive attitude to the other team members.	1.89	0.32			
	1.5 Displays resilience.	Keeps the compromises acquired in the framework of the team and the context of the ongoing project.	2.00	0.00			
	1.6 Resolves conflict constructively.	In the case of a conflict, mediates and collaborates effectively in the solution of the conflict.	1.71	0.49			

Appendix 3. Correlation matrix of the B1 competency for the team members

Table A 4. Block of the correlation matrix for the team members related to competency B1, *Human interaction and versatility*.

Competency	Descriptors	Pinpointed Behaviors	#	1	2	3	4	5	6	7	8	9
1. Human Interaction & Versatility	1.1 Communicates effectively in interpersonal and group situations.	Expresses clearly her/his ideas and opinions to the others during the group meetings.	1	1.00	0.58	0.84	0.52	0.53	0.32	0.39	0.50	0.49
		When working with others, listens to other's opinions and makes sure (for example, by asking questions) that he understand other's ideas or points of view.	2	0.58	1.00	0.54	0.58	0.60	0.33	0.32	0.54	0.40
	1.2 Able to translate thoughts into oral and written communication.	The ideas are clearly expressed, either orally or written, either in group meetings, interviews, and reports or other circumstances related to the work.	3	0.84	0.54	1.00	0.52	0.53	0.31	0.41	0.53	0.49
	1.3 Adapts behavior and work method in response to changing conditions.	In the case of a failure of a procedure, erroneous result during the work, in the case of the need of a change, looks for a new solution or approach, adapts to the new conditions.	4	0.52	0.58	0.52	1.00	0.57	0.39	0.47	0.49	0.47
		When he/she has to change the role inside the group, when new tasks are addressed, adapts easily and effectively to the new role or to the new task.	5	0.53	0.60	0.53	0.57	1.00	0.49	0.52	0.78	0.69
	1.4 Deals effectively with high workload.	When tasks are distributed or workload is increased, does not complain and positively faces the new workload.	6	0.32	0.33	0.31	0.39	0.49	1.00	0.51	0.60	0.36
		In the moments of high workload expresses or encourages to a positive attitude to the other team members.	7	0.39	0.32	0.41	0.47	0.52	0.51	1.00	0.57	0.60

Appendix 3. Correlation matrix of the B1 competency for the team members

	1.5 Displays resilience.	Keeps the compromises acquired in the framework of the team and the context of the ongoing project.	**8**	0.50	0.54	0.53	0.49	0.78	0.60	0.57	1.00	0.64
	1.6 Resolves conflict constructively.	In the case of a conflict, mediates and collaborates effectively in the solution of the conflict.	**9**	0.49	0.40	0.49	0.47	0.69	0.36	0.60	0.64	1.00

Appendix 4. Comparison between internship and instrument's evaluation of the leaders

Table A 5. Comparison between the grades obtained in the internship and the grades obtained with the instrument.

Internship										
	Leader 1	Leader 2	Leader 3	Leader 4	Leader 5	Leader 6	Leader 7	Leader 8	Leader 9	Leader 10
B1. Human Interaction & Versatility	6.0	7.0	7.3	9.7	6.3	8.0	10.0	8.7	7.3	7.3
B2. Facilitative Leadership	6.0	8.7	7.0	9.9	7.3	8.7	10.0	8.7	7.3	7.7
B3. Teamwork	6.3	8.3	7.8	9.9	8.3	8.5	10.0	8.8	8.0	7.8
B4. Active Learning & Responsibility	6.0	8.0	7.7	9.9	8.0	8.3	10.0	8.7	8.3	7.7
B5. Initiative & Innovation	6.0	8.5	6.0	10.0	6.0	8.0	10.0	8.0	6.5	6.5
Instrument										
	Leader 1	Leader 2	Leader 3	Leader 4	Leader 5	Leader 6	Leader 7	Leader 8	Leader 9	Leader 10
B1. Human Interaction & Versatility	9.7	8.5	9.0	8.7	8.5	6.9	8.6	9.3	6.8	9.2
B2. Facilitative Leadership	9.7	7.8	8.8	8.6	8.6	7.4	7.3	9.4	7.4	9.2
B3. Teamwork	9.5	7.1	8.7	8.7	8.5	7.1	9.0	9.4	7.0	9.1
B4. Active Learning & Responsibility	9.7	8.3	8.9	8.3	8.7	7.2	8.6	9.5	7.0	8.9
B5. Initiative & Innovation	9.5	10.0	8.3	8.4	8.2	7.1	8.1	8.9	6.6	8.6

UNIVERSITAT ROVIRA I VIRGILI
VIRTUAL PROFESSIONAL ENVIRONMENT: A METHOD FOR THE EDUCATION AND EVALUATION THROUGH COMPETENCIES.
Francisco José Suñé Grande
Dipòsit Legal: T 271-2015

Appendix 5. Items evaluated in the internship and their correspondences to ETSEQ competencies.

The supervisor of the internship has to fill in the following questionnaire and send to ETSEQ to evaluate the student.

EVALUATION OF THE INTERNSHIP (Supervisor)

Technical skills		Cooperation	
Grade from 0 to 10		Grade from 0 to 10	

Productivity		Communication	
Grade from 0 to 10		Grade from 0 to 10	

Initiative		Communication at work	
Grade from 0 to 10		Grade from 0 to 10	

Creativity		Quality of the work	
Grade from 0 to 10		Grade from 0 to 10	

Responsibility		Languages	
Grade from 0 to 10		Grade from 0 to 10	

Figure A 1. Items evaluated by the supervisor of the internship.

In Table A 6, we show the correspondences between these items and the five social competences of the ETSEQ.

Table A 6. Correspondences between ETSEQ social competences and items evaluated from the internship's supervisor.

ETSEQ competencies	Items evaluated in the internship
Human Interaction & Versatility	Productivity
	Communication
	Communication at work
Facilitative Leadership	Initiative
	Responsibility
	Quality of the work
Teamwork	Cooperation
	Productivity

Appendix 5. Items evaluated in the internship and their correspondences to ETSEQ competencies

	Quality of work
	Responsibility
Active Learning & Responsibility	Productivity
	Quality of work
	Responsibility
Initiative & Innovation	Initiative
	Creativity

As we can observe in Table A 6, we consider that the average of Productivity, Communication, and Communication at work can be compared with the grade of Human Interaction & Versatility. We have used the same procedure to calculate the estimation of the other competencies.

Appendix 6. Principal Component Analysis of the population

In the population analysis, we have calculated the eigenvectors and the eigenvalues of the students through PCA. We did the PCA with the population of the first year and the second year.

First year's PCA

Table A 7. Eigenvalues and eigenvectors of the principal component analysis of the competencies of team members of the first course, considering the technical competency (*A*).

Eigenvalues	**0.10**	**0.12**	**0.14**	**0.27**	**0.80**	**4.58**
Eigenvectors						
B1	0.63	-0.56	-0.28	-0.10	0.04	0.45
B2	-0.60	-0.44	0.07	0.49	0.09	0.44
B3	0.33	0.61	0.01	0.57	0.09	0.43
B4	0.01	0.06	0.77	-0.44	0.13	0.43
B5	-0.35	0.32	-0.57	-0.48	0.18	0.43
A	-0.06	0.06	0.00	-0.06	-0.97	0.23

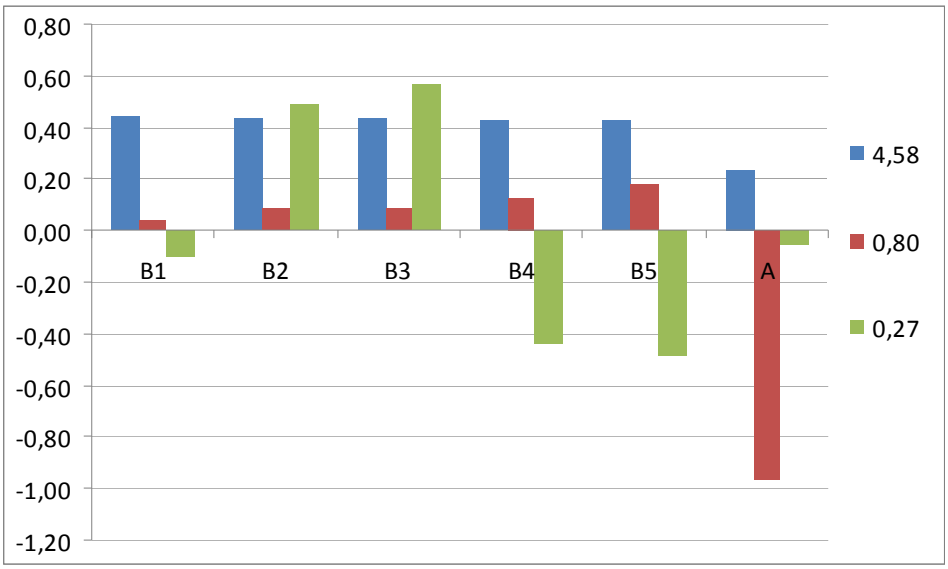

Figure A 2. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the team members of the first course and taking into account the technical competency (*A*).

Table A 8. Eigenvalues and eigenvectors of the principal component analysis of the competencies of team members of the first course, without the technical competency.

Eigenvalues	**0.10**	**0.12**	**0.14**	**0.27**	**4.37**
Eigenvectors					
B1	-0.55	-0.64	0.27	0.09	0.46
B2	0.67	-0.34	-0.07	-0.48	0.45
B3	-0.40	0.58	-0.01	-0.56	0.44
B4	-0.02	0.07	-0.77	0.45	0.44
B5	0.31	0.36	0.57	0.50	0.44

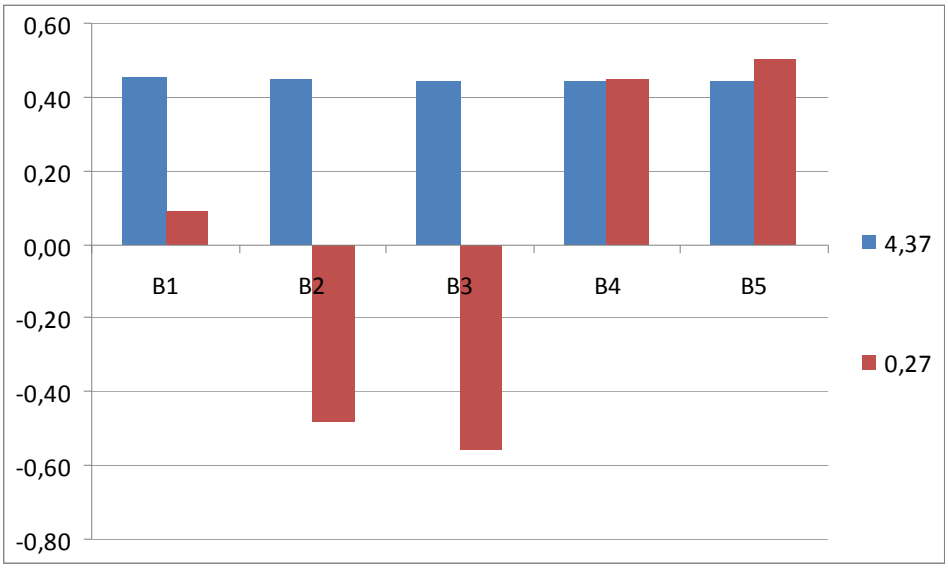

Figure A 3. Graphical representation of the two first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the team members of the first.

Table A 9. Eigenvalues and eigenvectors of the principal component analysis of the competencies of the leaders of teams of the first course (students of the fourth course).

Eigenvalues	**0.06**	**0.06**	**0.29**	**0.55**	**4.04**
Eigenvectors					
B1	-0.14	-0.86	-0.06	-0.02	0.49
B2	0.01	0.18	0.87	0.17	0.43
B3	-0.48	0.34	-0.39	0.56	0.44
B4	0.81	0.16	-0.29	0.03	0.48
B5	-0.30	0.29	-0.10	-0.81	0.39

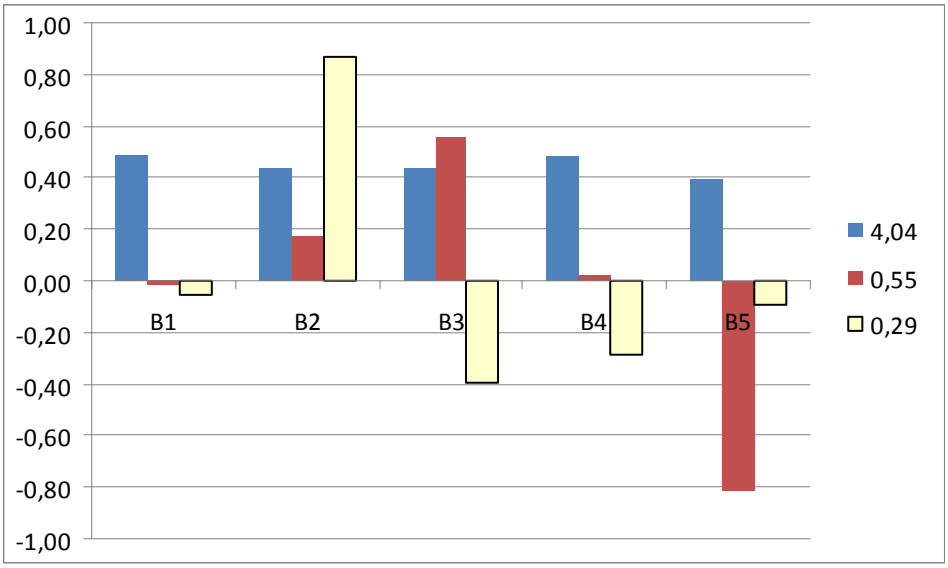

Figure A 4. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the leaders of teams of the 1st course (students of the fourth course).

Second year's PCA

Table A 10. Eigenvalues and eigenvectors of the principal component analysis of the competencies of team members of the second course, considering the technical competency (*A*).

Eigenvalues	**0.07**	**0.08**	**0.13**	**0.20**	**0.95**	**4.57**
Eigenvectors						
B1	-0.44	0.55	0.48	-0.25	0.13	0.44
B2	0.71	-0.22	0.23	-0.41	0.17	0.44
B3	-0.33	-0.17	-0.72	-0.38	0.04	0.44
B4	0.33	0.46	-0.31	0.62	0.02	0.44
B5	-0.29	-0.64	0.31	0.46	-0.04	0.44
A	0.07	0.06	0.05	-0.13	-0.97	0.15

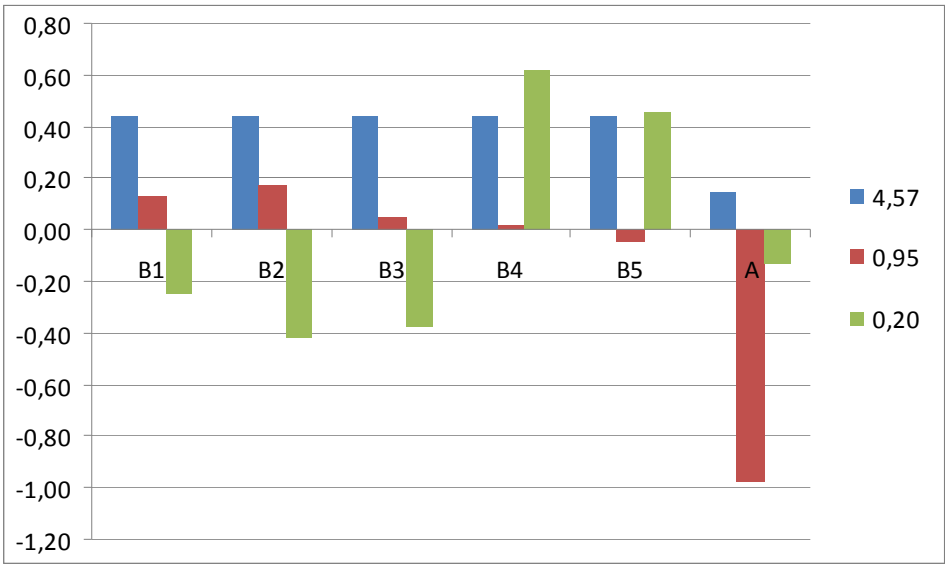

Figure A 5. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the team members of the second course and taking into account the technical competency (*A*).

Table A 11. Eigenvalues and eigenvectors of the principal component analysis of the competencies of team members of the second course.

Eigenvalues	**0.07**	**0.08**	**0.13**	**0.21**	**4.50**
Eigenvectors					
B1	0.59	-0.37	0.47	-0.30	0.45
B2	-0.72	0.06	0.22	-0.47	0.45
B3	0.26	0.23	-0.77	-0.30	0.45
B4	-0.23	-0.59	-0.22	0.59	0.44
B5	0.10	0.68	0.30	0.49	0.45

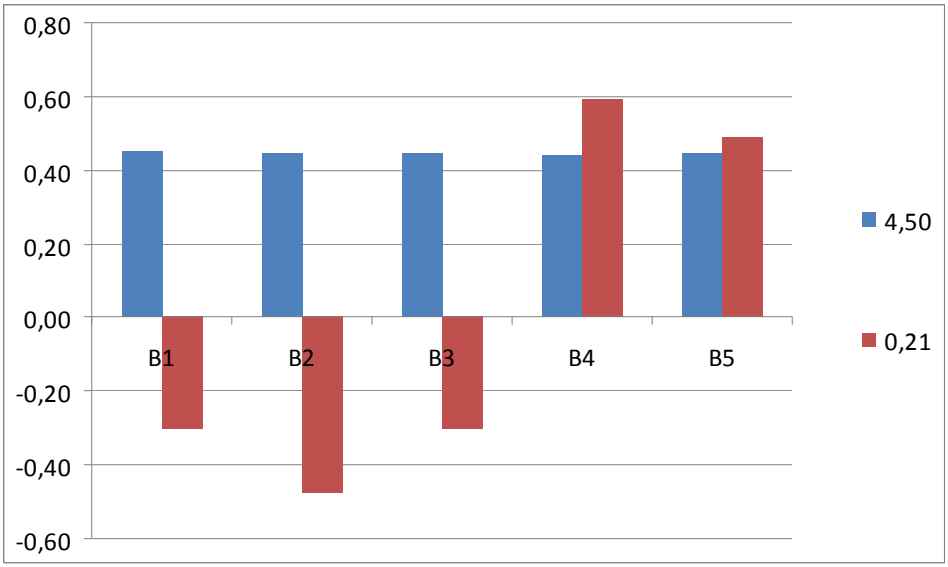

Figure A 6. Graphical representation of the two first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the team members of the second year.

Table A 12. Eigenvalues and eigenvectors of the principal component analysis of the competencies of the leaders of the second course, considering the technical competency (*A*).

Eigenvalues	**0.02**	**0.11**	**0.32**	**0.97**	**1.22**	**3.35**
Eigenvectors						
B1	0.50	-0.59	0.20	0.00	0.35	0.49
B2	0.22	0.73	0.32	-0.27	0.05	0.50
B3	0.03	0.02	-0.87	-0.10	-0.15	0.46
B4	-0.75	-0.23	0.28	0.02	-0.21	0.52
B5	-0.18	-0.16	-0.04	-0.92	0.25	-0.17
A	-0.34	0.19	-0.17	0.27	0.86	0.03

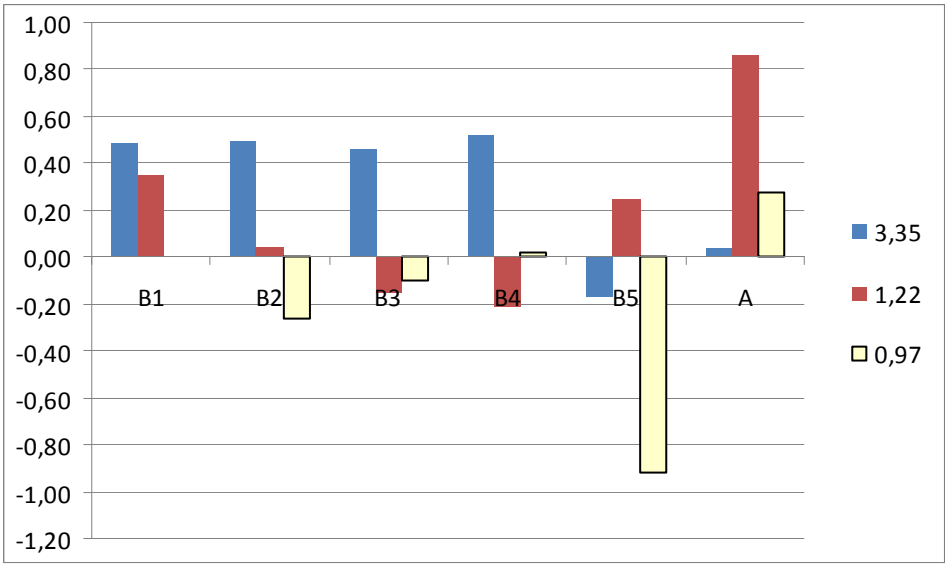

Figure A 7. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the leaders of the second course and taking into account the technical competency (*A*).

Table A 13. Eigenvalues and eigenvectors of the principal component analysis of the competencies of the leaders of the second course.

Eigenvalues	**0.08**	**0.20**	**0.38**	**0.99**	**3.35**
Eigenvectors					
B1	-0.04	0.68	0.53	0.14	-0.48
B2	0.63	-0.50	0.17	0.27	-0.50
B3	0.10	0.32	-0.82	0.03	-0.46
B4	-0.73	-0.43	0.04	-0.10	-0.52
B5	-0.25	-0.01	-0.10	0.95	0.17

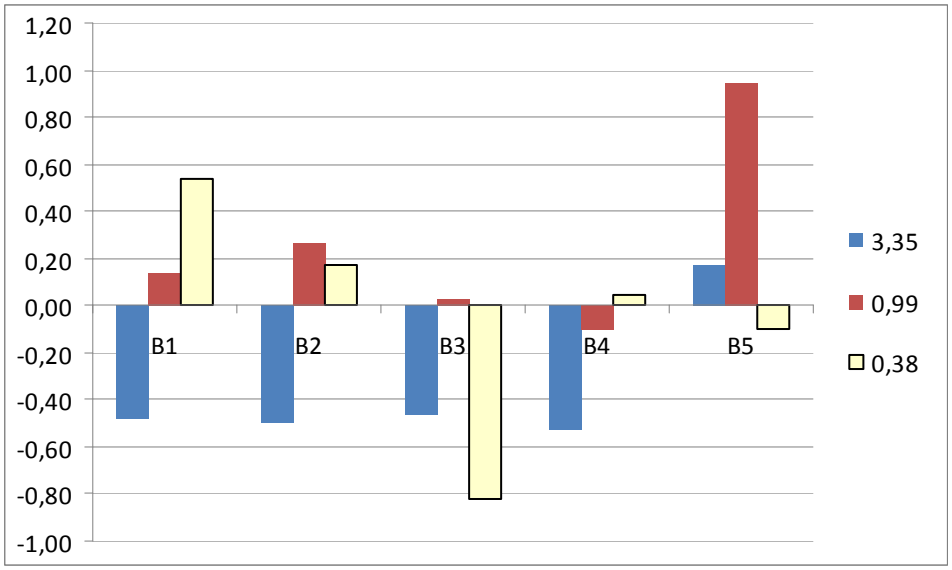

Figure A 8. Graphical representation of the three first eigenvectors in the PCA analysis, with their corresponding eigenvalues for the leaders of the second course.