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Providing Professional Skills to Telecommunication Engineers through a Novel Vertical Approach*

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The new context of the European Space of Higher Education and the current social environment marked by new technologies implies that new Telecommunication Engineers must be trained not only in technical knowledge but also in the professional skills that they must use in their professional lives. Some learning methodologies, such as Project-Based Learning help develop these skills. This paper presents projects developed in order to teach and assess different skills. The methods used change depending on the year of the academic program. The projects have been designed to focus on "process skills": The ability to work in a multi-disciplinary team, understanding of both professional and ethical responsibility and the ability to communicate effectively. The projects have been assessed through multi-source feedback combined with the use of rubrics to facilitate the evaluation. According to the results, most of the objectives have been achieved. Student satisfaction is very high, as the survey results demonstrate.

Keywords: engineering education; engineering professional skills; program implementation; project-based learning

1. Introduction

At present, the European Union is in the process of adapting university studies to European Higher Education Area (EHEA) requirements in order to comply with the Bologna Declaration [1]. The objective of these changes is to make teaching more student-centered and for students to participate more actively in their learning [2–3]. The effectiveness of hands-on experience to produce meaningful learning is demonstrated by our own research [4–5] as well as through results obtained by other authors [6–7]. The benefit of using teaching methods of this type is applicable to any field or discipline, but especially in the case of engineering. As reflected by the National Research Council's Boards of Engineering Education recommendation for engineering degree programs and training to "including early exposure to 'real' engineering and more extensive exposure to interdisciplinary, hands-on, industrial practice, team work, systems thinking, and creative design" [8]. That is, practical experience is of primary importance. However, universities have traditionally been good at imparting knowledge, but not in professional training, or "know-how", as noted in this project [9]. Thus, it is necessary to train university students in specific professional skills. In order to achieve this, over the last few years the ABET engineering criteria [10] and the influential work by Shuman et al. [11] have served as guides professional skills.

Among the professional skills identified in the literature as crucial for the professional life of an engineer, we have selected a set of four skills developed in four different projects. These skills include communication, multidisciplinary teamwork, leadership and ethics and professionalism. Based on our previous experience in teaching active methods [4–5], a vertical teaching methodology approach that allows the gradual evolution of professional skills throughout a complete Telecommunications Engineering program has been proposed.

The paper is organized as follows. In the next section, the details of the implementation of the vertical approach and focus on the teaching method are described. Section 3 describes the evaluation of professional skills in previous projects, including specific recommendations for assessing professional skills during the learning process. Section 4 defines the future issues. Finally, we discuss experimental results followed by the conclusions in Section 5.

2. Teaching-learning methodology

Active learning has received considerable attention over the last several years as an alternative to traditional teaching methods. Specifically, Problem-based & Project-based learning have been selected as useful instructional methods. In Problem-based learning students are confronted with an open-ended, ill-structured, authentic (real-world) problem. Whereas, Project-based learning begins with an assignment that leads to the produc-

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tion of a final product—a design, a model, a device or a computer simulation [3]. Both are always active and collaborative and, typically, involve significant amounts of self-directed learning on the part of the students [9]. Problem-Based & Project-Based Learning fit in to the ascendant (or vertical) nature of the learning process in this case study, and the self-guided nature of the learning method allows the students to discover the relationship between the projects they are presented with. In Table 1, different projects are shown, together with the year they are completed in the Telecommunication Engineering degree. The next subsection focuses on the vertical approach.

2.1 Vertical approach

The project presented in this paper has been implemented throughout the Telecommunications Engineering degree at the University of Extremadura. This degree is four years long. The aim is that through the different academic years, the students progressively acquire professional skills in addition to technical skills. To achieve this aim, PBL methodology has been used in each academic year to develop professional skills related to each subject. In Table1, at least one example of a yearly PBL activity is shown. The professional skills taught in each course are also shown. The possibility of experiencing a program such as this one allows concrete skills to be practiced over several academic years. In the early years of the degree, PBL activity is mostly guided by the teacher, but in the final years, students take on the main role and the problem is resolved smoothly without strict rules and excessive guidance. This fact increases the students' motivation and gives the teachers the opportunity to develop the skills that are being taught. As can be seen in Table 1, the most complex professional skills such as leadership are taught when the students have followed this learning methodology for a few courses. This way, the students encounter similar situations to those they will come across in their professional life and they will be able to deal with them successfully.

2.2 Individual project description

The projects have been eminently practical and the methodology implemented was PBL. All the tasks have a double objective, firstly to train the student in professional skills and secondly for the student to achieve the learning outcomes. The tasks were designed with the maximum degree of fidelity in order to achieve greater more transfer learning [9]. In this sense, we have followed the fidelity principle [10] in choosing activities. Fidelity is defined as the similarity of the training situation to the student's present and future working conditions. The higher degree of fidelity implies greater transfer learning for the student. Thus, the projects developed match real-world projects that telecommunication engineers develop in their professional lives. Moreover, to maximize the fidelity the form and verification process of the Professional Association of Telecommunication Engineering have been added to the two first projects. In these two projects "WIMAPS" and "TELINF" the structure is very similar and the skills developed are the same. The difference is that "WIMAPS" is more centered in the skill "oral communication" and "TELINF" is more centered in the skill "Ethics and professionalism". On the other hand, "STRUCTCAB" and "QUATRAFFIC" are focused on teamwork skills. "STRUCTCAB" is a project developed in the first year of the degree and the general teamwork skills are taught, whereas "QUATRAFFIC" is developed in the last academic year and it focuses on leadership, one of the specific teamwork skills required for twenty-first century engineers. The individual projects are:

2.2.1 Elective project "TELINF" and "WIMAP"

The project "TELINF" is a project in which all telecommunications infrastructure provided to buildings, (TV satellite and terrestrial, fiber optic, structured cable, home automation system, infrastructure telecommunication, etc.) are designed by the students. The main professional skill developed by the students in this project is "ethics and professionalism".

Table 1. Example of professional skills taught in courses with PBL

Project-Based Learning Activity	Project Acronym	Academic year	Main Professional Skills taught
Connection and wiring verification twisted pair network in a structured cabling system.	STRUCTCAB	1st	Teamwork
Making coverage maps for wireless networks.	WIMAPS	Elective subject	Oral communication
Creating a CTI (Common Telecommunications Infrastructures) project for the University Center of Merida, administrative building.	TELINF	Elective subject	Ethics and professionalism
Quality of Service (QoS) and Traffic Engineering (TE) in high-speed switched networks.	QUATRAFFIC	4th	Leadership

In the project "WIMAP" the students developed a Wi-Fi network for the campus. In addition the students are required to measure Wi-Fi and cellular network coverage. The main professional skill developed by the students in this project is the ability to communicate effectively.

Both projects were developed in order to achieve several learning outcomes, but overall to develop different skill such as "ethic and professionalism" and "oral communication". In order to develop "oral communication" skill in both projects, each group had to choose to use different technology to complete the different project. In different situations, several groups discuss which is the best technology to develop the different parts of the project. First, each team presented to the other team their solution and after this each team had to criticize/defend the technological solution of the other/own team. Each group tried to demonstrate that their technology is the best through the discussion and debate. In addition, as a transversal content, both projects were be related to the development of smart cities, one of objectives of Digital Agenda of European Union for research and develop [10]. Thus, the students are required to implement "green solutions" in order to develop their ethical responsibilities as an engineer. This section played an important part within the project and independent evaluation. That is, the teachers try to raise students' awareness of the impact of engineering solutions in a global context and the importance of issues such as sustainability and development (one of the ABET criteria). Finally, this experience provides an added value to the students. It deals with smart and green cities, one of the most relevant topics in engineering and a niche of professional opportunities.

2.2.2 Connection and wiring verification twisted pair network in a structured cabling system "STRUCTCAB"

In this project, students learned how to organize data network infrastructure at the physical layer through Structured Cabling Systems (SCS), while developing professional skills such as teamwork. It was developed in four phases. First, the teacher introduced fundamental concepts and the regulatory framework. It also provided a framework for organizing the next phases. Then, the working groups reviewed the proposed literature on patching techniques and SCS testing to prepare a work schedule. Each group presented its plan to the other groups and discussed them. In the last phase, the teacher gave a demonstration of patching techniques and security measures. Finally, each group independently performed the tasks planned for installation and testing of their own pilot SCS.

2.2.3 Quality of Service in High-speed switched networks project "QUATRAFFIC"

This project is about bandwidth networks and their capacity to offer Quality of Service (QoS) and Traffic Engineering (TE) in data communications. The goal of the project is to design an innovative networking solution for a company that has particular needs in terms of both throughput and delay guarantee, making it necessary to use quality of service and traffic engineering solutions. The main professional skill developed in this subject is leadership. This skill was selected to be taught in this subject because it is given in the fourth year of the degree. In the last year of the degree, the students must understand the impact of their decisions, the consequences of leading a group and the importance of guiding your team in the right direction.

3. Evaluation of professional skills

This section is divided into three subsections, in the first one, the assessment of different individual projects are described in detail, in the second the benefits of the approach followed to promote professional skills are explained and finally in the last methodology adopted is evaluated.

3.1 Assessment of individual project

One of the most important challenges in the project is the evaluation and assessment of professional skills. Each skill is evaluated similarly in every course that it is taught. Moreover, both the methodology and the skills taught are evaluated through rubrics [10]. The students must play an important role during this process, and also in the evaluation. Some techniques are used to increase student participation, for example, peer-evaluation of each solution or the possibility of giving a global mark for a whole group that the students then decide how to distribute amongst themselves.

3.1.1 Assess of projects "TELINF" and "WIMAP"

The assessment of the skills acquired are made through rubrics, in both projects the same rubrics were used. In order to assess oral communication skills and the development of ethical responsibilities as engineers through "green" solutions a unique rubric for both skills was used. The rubric used is shown in Table 2. Specifically indicators 1–5, 7, 9, 11 and 13–15 are for the assessment of oral communicative ability and points 6, 8, 10 and 12 are for the evaluation of the responsibilities of engineers. Through the rubrics, the students were evaluated both by teachers and by themselves. Two evaluations were made in projects, the first one assessing oral communication skills and the second assessing

Table 2. Rubric for the Projects "TELINF" and "WIMAP"

	1	2	3	4
1.—Exposure of the technical solution	The technical solutions is very poor.	The technical solutions is poor in general, but some technical solution can be spotted.	The technical solutions is good, but some question are unsolved.	The technical solutions are very good.
2.—Speech Organization	Technical solution are exposed directly, without anticipating even number.	Only the number of technical solution are expected.	They anticipated and classified the arguments or ideas, but does not summarize during exposure scheme.	They anticipated and classified the arguments or ideas, which are taken over and/or graphically support.
3.—Relevance and clarity of the argument	The arguments are not presented or not really related with the technical solution.	The arguments correspond to the technical solution but some of them are irrelevant or misunderstood.	The arguments are relevant but they are briefly exposed or with low explicitness.	The arguments are relevant and clearly expressed (specifying the assumptions, conclusions and justifications).
4.—Foundation of the argument	No evidence offered nor premise or justification of the claims that are made.	The arguments are based on opinion or particular experiences.	Some arguments are based on evidence, but these are questionable.	Most of the arguments are based strictly on empirical evidence.
5.—Diversity and depth of the argument	Arguments are presented do not really answer the question for debate.	The argument is simple and based on a single idea.	Several arguments are relevant, but the storyline is simple (derived from a single premise) or is implied.	Explains various complex arguments (which are derived from several premises or of a chain articulated explicit plot).
6.—Green solutions	No solution is mentioned.	They mention a "green solution" but they not able to relate to the project.	They propose "green solutions" and relate this with the project.	Proposes "green solutions" and quantifies the impact of the same in the project in terms of improving.
7.—Questions, Comments and Rebuttal	Not interpellates to the other groups.	The refutation is confusing or too vague.	It identifies potential errors in the opposite exposure, but are not relevant or do not affect the storyline.	Clearly identify the main biases or inconsistencies in the arguments of the opposing team.
8.—Questions, Comments and Rebuttal about "Green solutions"	Not related to the other groups "Green solutions".	The refutation of "Green solutions" is confusing or too vague.	It identifies potential errors in the opposite exposure of "Green solutions", but are not relevant or do not affect the storyline.	Clearly identify the main biases or inconsistencies in the "Green solutions" of the opposing team.
9.—Replica	No answers to most inquiries.	The defense does not include the content of inquiries or based on mere repetition of arguments.	The defense explicitly responds to most inquiries, but is somehow unconvincing.	They consistently defended the position against all or almost all the counter-arguments.
10.—Replica about green solution	No answers to most inquiries about "green solutions".	The defense does not include the content of inquiries about "green solutions" or based on mere repetition of arguments.	The defense explicitly responds to most inquiries about "green solutions", but is somehow unconvincing.	They consistently defended the position about "green solutions" against all or almost all the counter-arguments.
11.—Conclusions	No conclusions are presented or are either irrelevant, inconsistent or confusing.	Relevant conclusions are exposed but not justified nor recapitulated.	Summarizes the arguments and counter-arguments, but the findings are not clearly derived.	Based on a summary of the arguments and counter-arguments, relevant conclusions are formulated.
12.—Conclusions about green solution	No conclusions are presented about "green solutions".	Relevant conclusions are exposed about "green solutions" but not justified nor recapitulated.	Summarizes the arguments and counter-arguments about "green solutions", but the findings are not clearly derived.	Based on a summary of the arguments and counter-arguments about "green solutions", relevant conclusions are formulated.

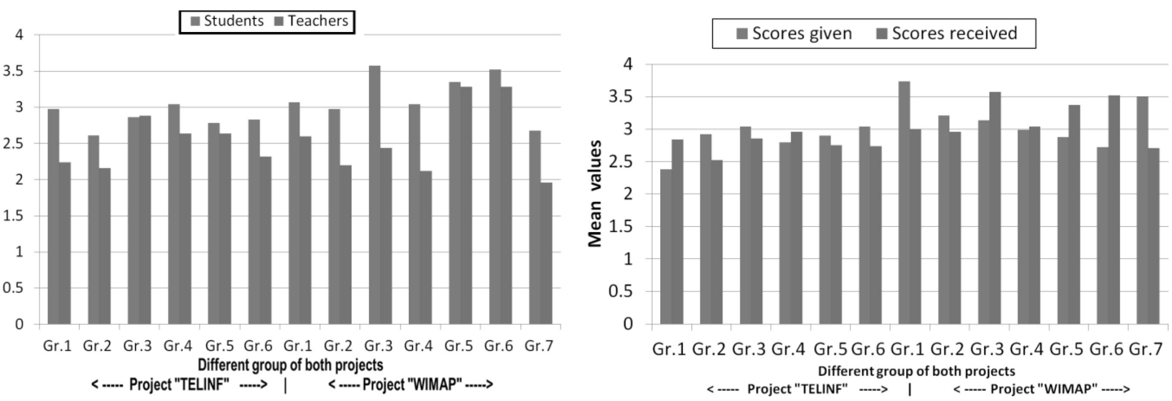
Table 2.—*continued.*

	1	2	3	4
13.—Verbal language	The language is usually very poor or disrespectful.	The language is respectful and courteous, but often vague and inarticulate.	The language is respectful and accurate, just sometimes eloquent.	The language is respectful and eloquent (incorporating rhetorical emphasis, humor, etc.).
14.—Nonverbal Communication	Inappropriate gestures are adopted, reading the arguments or not looking at the interlocutor.	Appropriate gestures are adopted, but the voice is usually monotonous or without the appropriate volume.	Body posture, gaze, gestures, silences, volume, tone, etc.., are correct but non eloquent.	Body posture, gaze, gestures, silences, volume, tone, etc.., Is correct and eloquent.
15.—Rules for Participation	Interventions do not conform to the established time and/or turns not respected.	Some interventions do not respect the rules and/ or a team member assumes almost the entire partition.	Interventions respect the times and turns, but some of team members not are involved.	Interventions respect the times and turns with a balanced participation of team members.

the two skills, That is, in the first evaluation (at half-time project) each group must expose the solution that they implemented (only item from 1–5 and 13–15 are evaluated) and in the second evaluation each group must present, defend and debate the solution implemented including green solutions (all items are evaluated).

The results of the first evaluation of both projects can be seen in Fig. 1a, which shows the mean scores obtained by the different groups (6 groups in "TELINF" and 7 groups in project "WIMAP"), considering the scores of students as teachers. Note that the average score given by teachers is lower than the average score given by the students. In addition, it should be noted that there is a correlation between assessments assigned by teachers and assessments assigned by the different groups. Finally it is important to note that the best rated groups are the lowest scored by other groups and vice versa as it is possible see in Fig. 1b. In other words, the group who did a very good job (Groups 3, 5 and 6 of project "WIMAP") perceive that their work is not goods well done, and those with a lower score (Group 2 of project "TELINF" and Group 7 of project "WIMAP") perceive that their work done is excellent.

Figure 2 shows the second evaluation for the second part of the project through the rubric shown in Table 2. Fig. 2a depicts the individual evaluation of each group whereas Fig. 2b details the staked evaluation. For this second part in the project "WIMAP" every second group came together in one group except group 7 which remained alone resulting in four new groups. In this Fig. 2 shows how the students obtained the best scores in the first 5 items and the last 2 (there are those that were assessed in the first part of the project), this fact gives us the evidence that oral communication competence is was acquired through the project. It is also observed that lower scores on the rubric are obtained in items related with ethics and professionalism (6, 8, 10 and 12); this can be observed in Fig. 2a clearly. It is important to note that group 2 in project "WIMAPS" obtained a high score in item 6 proposing solutions such as: "use only class A energetic appliances" and "use



(a) (b)

Fig. 1. First evaluation of oral communication skill. (a) Comparison between student and teachers. (b) Comparison between scores given and scores received for each group.

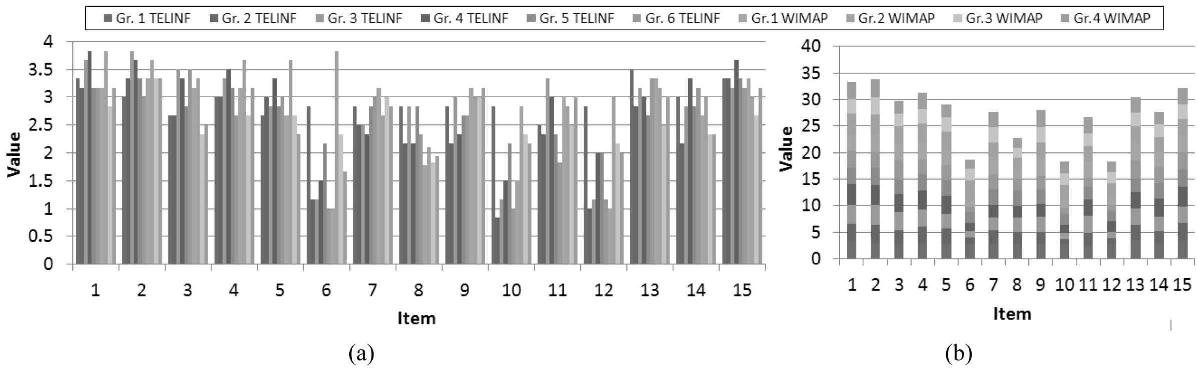


Fig. 2 Full skill evaluation of both projects. (a) Individually scores. (b) Staked scores.

sectorial antennas in order to have achieve maximum efficiency in coverage areas and avoid radiating power losses in unwanted areas" moreover they had quantified the impact of these solutions in their project (they had power savings up to 30%).

3.1.2 Assess of projects STRUCTCAB" and "QUATRAFFIC"

In this section we present the projects where teamwork-related skills are needed. These projects are STRUCTCAB and QUATRAFFIC. As is shown in Table 1, both projects deal with teamwork skills but it is important to point out that STRUCTCAB is undertaken in the first year of the degree, with students that have just arrived at university, whereas QUATRAFFIC is undertaken in the fourth year of the degree, where students have experience with PBL methodology and with a higher level of maturity. This implies that the former project assess teamwork skills from a generic point of view, whereas the latter assess other critical skills such as leadership, that also belong to the group of teamwork-related skills. Next, the assessments of both projects are explained and the rubric used to evaluate them is shown.

The assessment of the STRUCTCAB activity focused on two main aspects: (1) compliance with the learning objectives for the development of teamwork skills, (2) accomplish the general aim of the project to complete a technical assignment on a physical layer network model. The teamwork skills assessment was completed by an anonymous survey based on a rubric (Table 3) in which each student valued teamwork skills. The STRUCTCAB project is divided into four phases, the first one is an introduction to the activity and was not evaluated, so the aforementioned survey was conducted at the end of phases II, III and IV in order to have an idea regarding the evolution of the groups throughout the life of the project and an overview of the activity.

Figure 3 shows the average rating obtained for each category assessed for teamwork during phases II, III and IV. This is interesting because these are the phases during which students had to work together autonomously most of the time.

Based on the above, the following conclusions are drawn: during phase III, which corresponds approximately to half the lifetime of the groups, we obtained the lower score and a greater range of responses within the categories evaluated. This could be due to a natural maturing process of the relationships within the group. So, you can see a clear evolution in the views of the student throughout the life of project. The students had higher expectations for phase II and a real conception of teamwork during phase IV. Moreover, most students value positively or very positively all categories during all phases of the project, highlighting the category "Discussion and decision" (with 81% satisfactory answers) and "Respect, commitment, mutuality "(with 76.2% satisfactory answers), followed by "Participation" (with 66.7% satisfactory answer). Finally it should be noted that only 14% believed it was a waste of time after completion of the project.

With regards to the "QUATRAFFIC" project, the way the leadership skill was dealt with was a bit different due to the nature of the skill and the students (they are in the last year of the degree). Leadership is one of the required skills of twenty-first century engineers. Although traditional curricula have mainly been centered on educating technically competent engineers, modern engineers need to be aware of other issues beyond technical skills. The global, knowledge-driven economy has also resulted in a growing awareness of the critical importance of technological innovation to competitiveness, long-term productivity and growth, and the generation of wealth. Preeminence in technological innovation requires leadership in all aspects of engineering (practice, research and education) [12].

In many cases, the way to develop teamwork skills (leadership can be considered a teamwork skill) consists in simply giving three or four students

Table 3. Rubric for assessing teamwork and leadership skills

	1	2	3	4
1.—Participation	Almost everything completed by one or two members of the group without consulting others.	Almost all members of the group have been active, though some were unable or have not wanted to.	All have been active. But some only at times without sufficient involvement.	All have been actively involved in the activity and all the time.
2.—Planning, coordination	There has been no team planning. A few have done nothing or have not met (because they were not satisfied, or not well understood).	Everything completed by everybody l (no distribution of responsibilities), so taken too long.	The group has distributed some tasks and others were done by all, although planning has not been the best or lost too much time in meetings.	The group has distributed some tasks and others have been completed through good time management and working strategies. The meetings have been effective (someone has moderated the discussion, noted the agreements or conclusions, etc.).
3.—Discussion and decision	Discussed poorly. Almost everything has been decided by one or two people, without the opinion of others, or else, each has become a part without the others to review.	Discussed a lot, but some just participated or have not reached agreements (some decisions have been imposed, drawn or voted).	Discussed a lot, but often too loud, not listening to others or respecting speaking time.	Discussed a lot, come to agreements that were accepted by all. Generally, the discussions have been ordered.
4.—Respect, commitment, mutuality	Some have not met their minimal commitments, or there was a lack of respect or personal conflicts that are unresolved.	Generally the group has gotten along and all have worked, although the operating rules failed too many times (attendance, punctuality, etc.).	Generally the group has gotten along, all have worked and have followed the operating rules, although sometimes they have despised the opinion of a colleague or did not support those who had more difficulties.	Generally the group has gotten along. Although there have been some small conflicts they were resolved. They respected all opinions, even those that were wrong. It has supported those who have more difficulties.
5.—Interdependence	Very independent and competitive negotiating styles and a zero-sum gain.	Independent thought. Does not contribute actively to the rest of the team, and that effected the project negatively.	The student has difficulties cooperating, but understands that working together is necessary.	Cooperative negotiation style. The student has a clear interest in working together to achieve goals.
6.—Decision-making	Cannot identify needs and make decisions based on relevant technical information.	Identify some needs but seems to have difficulty in making the right decisions.	Ultimately identifies relevant needs but the decisions are not consistent technically.	Consistently identify relevant needs and makes correct decisions that benefit the ongoing work of the group.
7.—Team building	The leader did not develop the team; the team did not function well.	The leader made some effort in developing the team but it did not function as expected.	The leader made efforts in developing the team and it works as expected.	The leader developed team interaction and cooperation to achieve a well-functioning team.
8.—Regular self-assessment	The student never reflects on their work in the group.	Some reflection is made but there are not corrective actions.	The student analyses their work regularly, but there are not clear benefits for the team in corrective actions.	The student reflects on their work and reaches conclusions about how to improve leadership in the team.
9.—Leadership disposition	Does not demonstrate any leadership at all. Lets others set and pursue the project goals and scheduling.	Assumes a leadership role in a very limited capacity, but needs guidance.	Exercises good leadership and can guide others.	Demonstrates natural leadership abilities beyond expectations by taking initiative and guiding others. Takes a large part in setting group goals and project scheduling.

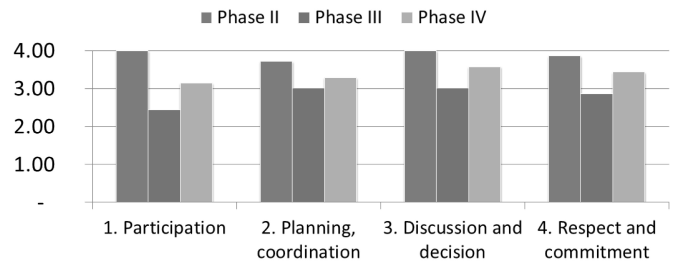


Fig. 3. Assessment results of the teamwork skill by category and project phases.

something to do together to enable skills related to teamwork [13]. Unfortunately, it is not so easy for critical and complex skills such as leadership, decision-making or conflict resolution. From this perspective, the method we used to promote leadership skills was based on positive interdependence (if anyone in the team does not fulfill his/her responsibilities, everyone is penalized in some manner), learning from incorrect decisions, appropriate use of interpersonal skills or team building behavior and regular self-assessment. As can be seen in Table 2, these issues have been evaluated in the leadership rubric in order to ensure the skill is assessed. The specific leadership indicators in the rubric shown in Table 2 are in rows numbered from 5 to 9. These 5 indicators have only been evaluated in QUATRAFFIC project. The previous indicators (from 1 to 4) are common teamwork indicators that were used both in STRUCTCAB and QUATRAFFIC projects.

The reason to work this way is that teamwork skills are developed through the STRUCTCAB project, in the first year of the degree, whereas specific teamwork skills such as leadership is developed at a more advanced point in the degree program in order to allow students to work in critical and complex skills, closer to the professional activity of a twenty-first century engineer. Next, the method used in this project to assess the leadership skill is presented.

The class is divided into different teams for the project, by groups of 4 students. Each group has to work in a simulated team experience in order to complete a real design project [14]. In this real situation, a team of engineers is working for a company in a Communications Department. The company needs to change their network, which is operating with outdated technologies, to meet the new needs of the company. These needs are related to the project topic, quality of service and traffic engineering. The students will deal with the economic aspects because a budget limitation forms part of the project statements. Therefore both economic and technological needs are given in the statement. Regarding the economic side, the teacher must be very specific with the project statement in order to ensure that the students find, on their own, the hardware they need to meet the project requirements and that this equipment is available in the laboratory.

A relevant aspect of the methodology used is that at the beginning of each session, in the classroom, the team meets for approximately 15 minutes and they debate the project, the role of each member for this session, and generate new ideas that can be used. During this time, the teacher participates in the team only as a listener, and no guidance is provided to students at this time and the students make their own decisions. Usually, the teacher just participates in order to assign the leadership role if this role is not changing appropriately.

The leadership skills are demonstrated by the role that each student takes in the meeting at the beginning of each class. Leadership skills are needed for the group to make final decisions and to solve a conflict when the rest of the group believes that the leader maybe wrong.

Because of the nature of the goals of this project, the assessment of leadership skills is necessarily qualitative and somewhat subjective. As in the rest of the PBL projects, we have used rubrics to ensure the assessment of leadership. Due to the subjective nature of this skill, the use of rubrics is very appropriate in this case because the idea of the rubrics is to create specific and uniform assessment criteria so that the role of subjective opinions would be minimized.

According to the 5 leadership-related indicators of the rubric shown in Table 3, Fig. 4 shows the results of the skill assessments. For each indicator, we show three values, two of them are the student's score at the beginning and at the end of the project and the third is the final mark obtained in this skill, assigned by the teacher. We can see how the students have improved the skill during the activity. All the indicators have been increased from the student's point of view, from a 6% in the case of "Regular self-assignment" up to a 43.7% in the case of "Team building". It is important to note that there is no relevant difference between the student's mark at

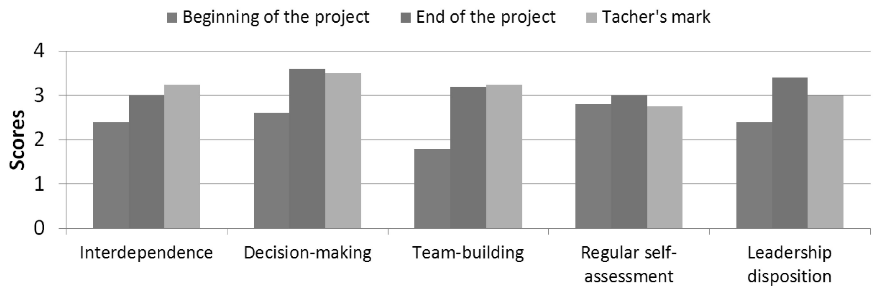


Fig. 4. Results of the skill assessments.

the end of the project and the teacher's mark. The average of the values the students' marks are 3.2% greater than the teacher's mark.

3.2 Benefits of the approach followed for promoting professional skills

The Vertical Approach is the name we have given to the development of professional skills distributed across the four years of the degree program. This has been done in order to provide the students with a complete program of professional development, both in technical skills (already developed in theoretical classes) and professional skills (less frequently incorporated into the degree program) however without considering sequencing the acquisition of these skills. We are convinced that just as with technical skills, the acquisition of certain professional skills is a pre-requisite for the development of others. This is well known in lower levels of education, especially in Language and Mathematics. It is difficult to understand certain concepts in Physics without having already learnt some Mathematics.

The professional skills developed in this project have been distributed throughout the four years of duration of the degree. We have designed this project as a vertical approach in order to complement the technical skills taught in the theoretical contents with the professional skills developed through the concept of "sequence of learning".

We are convinced that some professional skills must be acquired at a certain time in order to develop other ones more complicated. This process is similar to theoretical concepts that need previous knowledge to be understood correctly and is particularly evident in lower educational levels in which appear some foundation subjects such as mathematics or language. For example, a student will assimilate better a complex concept of physics if he understands the necessary math theory related with that problem.

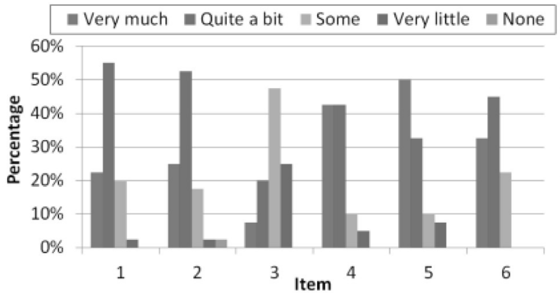
In the theoretical literature it is common to base the use of sequencing in a theoretical approach, such as the theory of elaboration developed by Reigeluth and Stein [15]. The basis of the Elaboration Theory is principally to establish how to organize, sequence, and present the teaching of certain content pertaining to some macro level. Reigeluth and Stein propose a spiral form of sequence beginning with a first simplest lesson, the "epitome", and then progressing in levels of increasing elaboration and complexity. Given our previous satisfactory results [4] and the scarcity of practical applications to teaching engineers using this powerful and solidly founded technology of instruction, we decided to use the aim of this theory in the determination of the correct sequence of development of professional skills in our vertical approach.

To do this, the more basic professional skills such as teamwork are assigned to lower level subjects in order to later introduce intermediate level skills such as oral expression, ethics and professionalism and finish with teamwork once again but focusing on leadership skills, thus completing the spiral employed in this approach to learning. The hope is that this will benefit the students by easing the development of professional skills through logical sequencing.

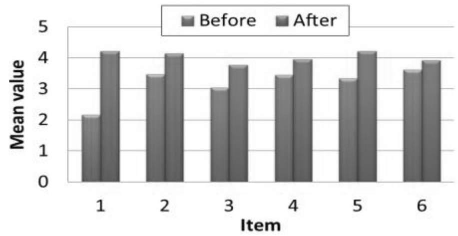
3.3 Evaluation of methodology and general satisfaction

The methodological assessment of the entire project was carried out with a questionnaire that was previously validated by a board of experts in Science Education and Telematics Engineering from the University of Extremadura. The final questionnaire contains questions to assess the dimensions related to the students Satisfaction and the Methodology.

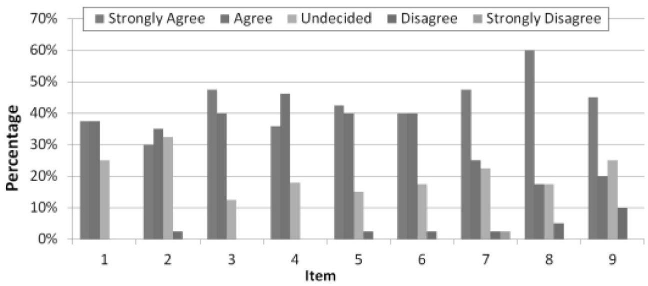
For the first dimension "Student satisfaction" two questions contained different items. The first one asks for the degree of satisfaction as a member of project and the second one is centered on the evolution of some skills from the point of view of the student. Specifically the question was "For you, working in this project was a . . . experience" with 6 different adjectives (items), graded in a Likert



(a)



(b)



(c)

Fig. 5(a) Review of the degree of satisfaction as a member or member of the project (b). Degree of student satisfaction at start and the end of the project in some attitudes and skills. (c) General assessment of the methodology used.

Table 4. Items from Figure 5

Item from Figure 5a	Item from Figure 5b	Item from Figure 5c
1. Enjoyable	1. Degree of knowledge of the subject studied	1. It motivates me to learn
2. Stimulating	2. Degree of confidence in the material	2. Promotes a better understanding
3. Effortless	3. Degree of flexibility of thinking	3. It helps me to deepen my knowledge of the subject
4. Satisfying	4. Degree of independence	4. It helps to correct misunderstandings
5. Formative	5. Degree of competition	5. I am encouraged to think
6. Creative	6. Degree of enthusiasm	6. It makes me improve my skills
		7. It helps me to relate the concepts of the course to real life situations
		8. I enjoy it more than with conventional classes
		9. I learn more than with conventional classes.

scale. The results for this question are summarized in Figure 5a and the items are shown in Table 4. In this one, it is possible to see that most of the answers are grouped around the two most positive indicators "Very much" and "Quite a bit". It is noteworthy that in the item where the indicator "Very much" has been chosen the most is item 5 (Formative) closely followed by item 4 (Satisfying). Moreover, it is notable that only in the case of item 2 (Stimulating) are there some answers in the indicator "None" while in the rest of the items this response was not chosen. From these results, it several conclusions can be made. For example, the students think that through the PBL project, they have learnt a lot and that this experience has not been easy (item 3 Effortless).

The results for the second question are illustrated in Fig. 5b, a summary of how they perceived their evolution from their own point of view before and after carrying out the PBL experience is shown. In all cases there has been a significant increase in the level of self-perception of acquisition in different skills such as the degree of independence and the degree of competitiveness, but especially noteworthy is the increase in the degree of knowledge of the subject studied. This could be due to the fact that participation in PBL obliges the students mentally relate and organize concepts that, although they had been explained in class, were not consolidated learning for most students. Therefore applying this knowledge in a real situation meant developing and deepening their knowledge of the material.

In the category "Methodology" up to 9 different items have been analyzed, which can be seen in the Table 4. From this category, the survey tries to extract the opinion of students about the methodology implemented. Only, in the case of item 7, which relates the contents of the subject to real life, only a small percentage chose "strongly disagree". Also in the case of the choice "Disagree" this research team needs to think about why in item 9, which measures the relationship between traditional classes and those using PBL there may be a small but illustrative number of students who doubt that they learn more in these kinds of classes. Anyway, as it is possible to see in the Fig. 5c, a considerable majority of students have chosen both "Strongly Agree" and "Agree" for all 9 items, clearly highlighting item 8 "I enjoy this class more than conventional classes". Finally, we would like to highlight some of the most significant comments and especially those most repeated by the students in response to the question: "what do you like most about the PBL project?" Examples of response were "Teamwork and solutions provided by my colleagues" and "The teamwork, the feeling that the whole group brings something". Response to the question: "what should improve in the project?" included, "less theory and more time to practice" and "Doing shorter lab practices, in order to do more"

Finally, the last question was regarding their overall opinion of the project and the results were the following: 17% extremely satisfied, 67% very satisfied, 13% moderately satisfied, 3% slightly satisfied and 0% not at all satisfied. These results are extraordinary, from our point of view, even more so given that the material covered dealt with was not especially appealing for the students when taught using a traditional approach.

4. Future issues

One of the future lines of research resulting from the completion of this research work is to study the evolution of the acquisition of skills by students under the Vertical paradigm used in this research. This development in the acquisition of skills can be influenced by the maturity of the student, the intrinsic difficulty of the skill and the vertical sequencing of the acquisition of the skill in this project. We propose in the future to track each student individually and assess trends in the acquisition of these skills. To this end we are studying the possibility of implementing a Web application in which each student's results are recorded for each skill in each subject. Using this tool to sequence and study the different skills throughout a degree program could optimize the results obtained. This will force us to work over several academic courses and, insofar as possible, with several groups of students, in order to implement different sequencing of skill acquisition and to find the optimal order in which to develop these skills in the curriculum of future telematics engineers.

5. Conclusions

In this work, a vertical case study for teaching professional skills in Telecommunications Engineering is presented. Four different projects were implemented in order to develop professional skills for students of telecommunications engineering. Each project is focused on a different professional skill and in each project the professional skill was evaluated through different rubrics that provide us an objective assessment of this different skill. Results show that the main objectives of the projects were achieved and the evaluation results demonstrate a high degree of compliance with curriculum goals and the overall the assessment of "soft skills" resulted in good feedback. Moreover, the results related with learning outcomes are better than in previous years, but some concepts are not well acquired. These results agree with other works, which claim that the results of working with practical experience are better but may not cover all learning outcomes

These good results also confirm the strategy of sequencing the acquisition of skills given that another strategy would have made it impossible to achieve such excellent results. The students, according to the satisfaction surveys, on the whole accepted the methodology used, meaning this method of learning professional skills is sustainable. However, even with good results are achieved in the acquisition of professional skills, if student or teacher satisfaction with the method were low it would be difficult to continue using this methodology because the overload for teachers. Finally, from our point of view these learning experiences are quite encouraging, given the positive feedback obtained and the enthusiasm and motivation showed by students.

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