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Improving Generic Skills among Engineering Students through Project-Based Learning in a Project Management Course

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Abstract
The speed of technological change, the increase in social exigencies, and the need to take good care of the environment, has made evident that engineering graduates must have generic skills of a holistic nature in order to successfully meet future professional challenges. This paper explains the impact of a project-based learning methodology on the improvement of generic skills. The methodology was used in an undergraduate industrial engineering project management course. Measurements of student knowledge and mastery of technical, contextual and behavioral skills were performed at the beginning and end of the course. Written questionnaires that measured the three dimensions were employed; the collected data was used in a statistical and a consistency analysis. The results indicate a significant improvement in student skills that can be attributed to the use of project based learning (PBL). It is known that PBL is only one of the many possible ways to improve generic skills, but it is a powerful tool that balances and complements an engineering curriculum that strives to develop the generic skills of engineering students.

Key words: generic skills, PBL, higher education engineering, Project management.

I . Introduction

Globalized and aggressive marketing has led organizations to develop new strategies and management models. From a project management perspective, these tendencies have created a special social and market scenario.

Global competition and the ever-changing market reality faced by young engineers require that universities provide their future professionals with more than technical skills. In order to practice professionally in the new global society, they must have professional skills. Although these skills will be strengthened during their professional employment, they must be nurtured at university. Information management, the ability to solve problems, initiative, creative decision making, and teamwork, will be indispensable engineering tools in the coming decades.

Engineers must be able to work in teams, thus requiring the development of personal skills. Furthermore, many teams are multidisciplinary and, due to the global reach of modern communication, team members are often not in the same physical location (or even the same country). Teams are formed according to skill requirements. This common work environment demands that engineering students feel comfortable and are able to use the most advanced technology to access information and communicate with others. It is therefore necessary that engineering programs provide students with awareness and a deeper understanding of teamwork, more than most current curricula offer [1].

Historically, technical education has been based on an analytical model (Science). Future teaching of engineering must be more inclusive [2]. Organizations seek and require engineers who are able to use the computer as a support tool, understand technology in a broad sense, with excellent analytical skills and problem solving abilities. However, the engineer must also be more holistic in approaches to problem solving. The development of the holistic engineer is an important challenge for engineering education.

Organizations are beginning to realize the vital role that people play in any project – people perform the work. Both communication among team members and management skills are essential for project success. Universities must take this point of view into consideration and increase their efforts to improve an engineering student's practical skills, including both soft and hard skills, plus tacit and explicit knowledge.

Project management includes a wide range of roles and responsibilities, and this must be reflected in educational programs. However, most universities focus solely on the development of an engineer's technical skills. These technical skills are easier to quantify compared with soft skills [3].

This paper analyses the impact of a project based learning (PBL) methodology on the improvement of generic skills among a group of industrial engineering students in a project management course. Section II presents an overview of PBL methodology and skill development. Section III describes the characteristics of the project management course which served as the case study. Section IV explains the data analysis and displays the statistical evidence that supports the Conclusions presented in Section V.

II. Project-based learning (PBL) and skills development

Professor William Heard Kilpatrick was the pioneer of project-based learning (PBL) in the early 20th century. His learning based on projects idea evolved from John Dewey's pedagogical model based on empirical experience. Dewey's 19th century work inspired Kilpatrick in 1918 to formulate a Project Method pedagogy. Kilpatrick, who had studied at and remained as a professor at Teachers College, Columbia University in New York, introduced the project method teaching concept in 1918 at the College. Unfortunately, it met with little popularity in the United States as it was judged too progressive [4].

In the 1970s, the method was rediscovered and fostered the idea of the project-based method linked to a conception of open curriculum and community education. Most recently, the project-based method is connected with the constructivist model. A more consistent application of the methodology is from the 1980s, highlighted by the experimentation of Arthur Kaufman and others [5], in the School of Medicine at the University of New Mexico. The School uses problem-based learning in simulated clinical cases [6].

John W. Thomas [7] defines project-based learning as "a model that organizes learning around projects." Projects are defined as complex tasks, based on challenging questions or problems, which engage students in design, problem-solving, decision making, or investigative activities. The projects give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations [8] [9].

A succinct definition would be: PBL is a method of teaching and learning in which students, working in teams during a specified period of time, complete a project to solve a problem through the planning, design and implementation of a series of activities, through the development and application of previously acquired knowledge and the effective use of resources. This results in experiential and reflective learning based on research for solving complex problems with open solutions, generating new knowledge and developing new skills. Students are expected to assume greater responsibility for their own learning, and implement in real projects the skills and knowledge acquired through their studies. It focuses on actions, it's not simply learning "about" something, but learning "to do" something [10].

The objective requires the accomplishment of one or more tasks that results in a final product, a design, a model, a device or a simulation. The culmination of a project is normally a written or oral report, which highlights the process that was followed to obtain the product, and the presentation of results. The emphasis of project-based learning is on the application or the integration of knowledge [11].

The teacher facilitates and guides the learning, but the student must engage the problem. Students pursue knowledge by asking questions stimulated by their natural curiosity; they develop their own inquiry approach, but receive guidance from a teacher. Student discoveries must be illustrated, thus creating a project to share with a chosen audience [12].

The PBL structure has four phases [10]:

- Information: Students gather the necessary information for the resolution of a planned task. The professor is not the main source of information.
- Planning: Elaboration of the project plan, structuring the methodology, planning, and selecting from among potential solution strategies.
- Realization: This includes research and experimental work, exercising and analyzing the creative, autonomous, and responsible action.
- Evaluation: Students report and discuss the results with the professor. They provide a written report of the project; the team presents the results to professors and peers. The evaluation should examine individual student knowledge concerning the project and the academic content.

The evaluation phase also includes self-assessment and reflection. Students reflect on how well they worked as a team and how well they contributed, negotiated, listened, and received the ideas of other team members. They also self-evaluate their projects, efforts, motivations, interests, and levels of productivity. Students become critical friends giving constructive feedback to each other, which helps them become aware of their own strengths and improve their ability to interact with each other [12].

De Graaff & Kolmos [13] indicate that a common difficulty faced by students in a project-based environment is transferring methods and competences acquired in a project to another project of a different discipline.

Prince and Felder [11] suggest that some students involved in project-based learning can have less developed engineering fundamentals, and may be unhappy over the time and effort required by projects and the interpersonal conflicts they experience in teamwork, especially with colleagues who fail to pull their weight.

Marx et al. [14] outline the following problems when teachers seek to apply project-based learning: project timelines are longer than expected; there is a tradeoff between the need to allow students to work by themselves and the need to keep order in the classroom; they have a constant need to control the information while at the same time understanding that students need to build their own knowledge; they have difficulty incorporating technology into the classroom as a cognitive instrument; and face the struggle of designing evaluations that provide evidence of student achievement.

The application of PBL with the proper characteristics for engineering students requires ensuring some preconditions such as: defining the number of team members; establishing team dynamics and the role of the professor; ensuring that students identify a problem, develop an action plan and use project management techniques (e.g. PERT, Gantt chart); defining milestones and project deliverables; encouraging students to exchange ideas with their team members and formulate various solution hypotheses before choosing the final one; defining the criteria and system of assessment; defining project timing and scope; and implementing the action plan and outlining a solution prototype.

Figure 1 shows a conceptual map of student and teacher core activities that are evaluated applying this methodology.

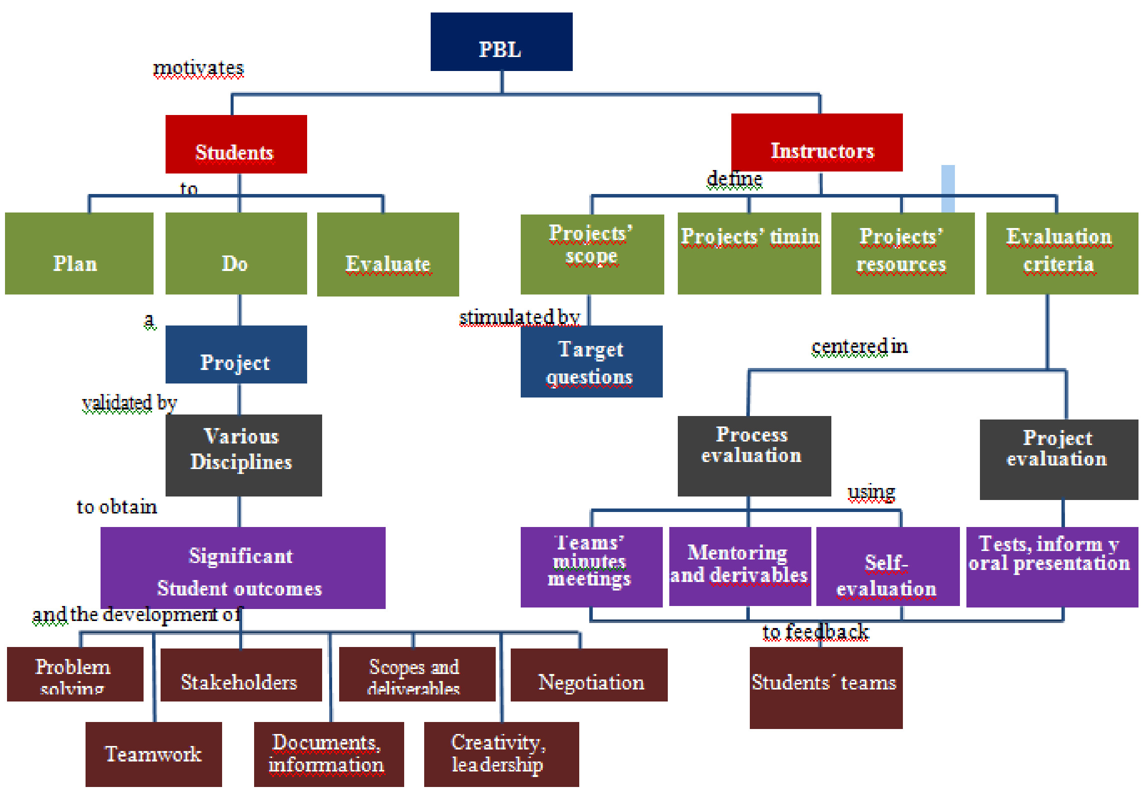

Figure 1. Conceptual map of PBL

Source: Adapted from Universidad Politécnica de Madrid [15]

An interesting experience of this learning process is described by the Escuela Técnica Superior de Ingenieros Agrónomos de la Universidad Politécnica de Madrid (Technical School of Agronomic Engineering of Universidad Politécnica de Madrid) [16] and the Government of the Community of Madrid. This methodology was applied to senior university students (students in the final year of studies) and it was concluded that several criteria must be met: both teachers and students should have a more active role, greater shared commitment, and in the particular case of the students, a greater responsibility with regards to their own learning. The experience mentioned above confirms that this methodology generates a learning process in which students are not passive recipients of knowledge, and the definition of projects with real content allows the integration of knowledge already acquired in other courses with the new knowledge generated during the project development. Personal skills are also developed; PBL allows students to learn how to work in teams, awakens a spirit of research and innovation, serves to motivate creativity for the generation of new knowledge and productive thinking, and encourages problem solving.

The Universidad Politécnica de Madrid document also states that the fundamentals of competences in project management defined by the International Project Management Association (IPMA) are adapted to facilitate training in technical, personal and contextual competences. This connection allows the linkage between higher education and a professional certification system, which opens up future opportunities for our graduates [16].

In the last decade, engineering graduates with superior personal or behavioral competences have been in high demand, and these competences are as essential to the engineer as technical competencies. IPMA and the Spanish Association of Project Engineering (AEIPRO), through its Project Management Certification Body (OCDP), have identified necessary competences in three areas: technical, behavioral, and contextual. Within these three areas, there are 46 elements required for a person who acts in a transparent manner for the benefit of the whole project, program or portfolio to meet the expectations of all parties involved [17].

The elements of technical competence describe what is required in the technical field to set up, manage, and close a project. The behavioral competence elements are applicable to the director of the project, the team members, and all involved parties, and are relevant for the interaction among them. The contextual competence elements describe the focus of project management to all areas involved. The holistic approach uses these classifications because they are suitable for determining a set of skills required by engineering graduates [18].

Table 1 describes the competences that were measured in this study.

Table 1. IPMA competences' elements

1. Technical competences	2.Behavioural competences	3.Contextual competences
1.01 Project management success.	2.01 Leadership	3.01 Project orientation
1.02 Stakeholders	2.02 Engagement and motivation	3.02 Program orientation
1.03 Project requirements and objective.	2.03 Self-control	3.03 Portfolio orientation
1.04 Risk and opportunity	2.04 Assertiveness	3.04 Project, program and portfolio implementation
1.05 Quality	2.05 Relaxation	3.05 Permanent organization
1.06 Project organization	2.06 Openness	3.06 Business
1.07 Teamwork	2.07 Creativity	3.07 Systems, products technology
1.08 Problem resolution	2.08 Results orientation	3.08 Personnel management
1.09 Project structures	2.09 Efficiency	3.09 Health, security, safety, and environment
1.10 Scope and deliverables	2.10 Consultation	3.10 Finance
1.11 Timing, Project phases	2.11 Negotiation	3.11 Legal
1.12 Resources	2.12 Conflict and crisis	
1.13 Cost and budgeting	2.13 Reliability	
1.14 Procurement and contracts	2.14 Values appreciation	
1.15 Changes	2.15Ethics	
1.16 Control and reports		
1.17 Documentation and information		
1.18 Communication		
1.19 Start- up		
1.20 Close-out		

Source: AEIPRO [19]

III. Project management course at the Universidad de Piura

Project Management is a course at the Universidad de Piura offered to seniors of the Industrial and Systems Engineering program. Its main purpose is to provide students with methodological tools based on general project knowledge, and the development of project management competences under IPMA [17] and Project Management Institute (PMI) [20] international standards.

It gradually introduces students to a real project situation, under a professor's tutelage. Through this process, the methodological tools and professional competences in project management are developed. PBL constitutes the primary learning and evaluation tool, but exams are also used and active participation is required.

At the end of the course, students should be capable of:

- Consolidating the project design, discussing its formulation and evaluation, knowledge areas, and project life cycle.
- Developing technical, behavioral, and contextual project management competences.

- Developing management roles in the identification of real market needs, project formulation and evaluation, and project management process and competences.

A brief description of how the project management course is delivered is presented below.

The course structure is developed through project management magisterial classes, seminars, conferences, and colloquiums. Self-study is also encouraged, through the use of information and communication technologies (TICs). Complementary readings and cases studies are available through the TICs. These are intended to promote the acquisition and development of project management competences.

During the semester, students must work as a group on the project, taking into account project knowledge areas and its assumed life cycle. There is a maximum of five students in each group, and the team members must coordinate the assignment of group tasks. Students are responsible for submitting partial deliverables of project management documents. The evaluation of the project is based on constructive feedback and is directly related with the primary project deliverables. Additionally, students are asked to complete two partial project reports.

The evaluation has three components: an initial and final student self-evaluation and the professor's evaluation (exams). The initial and final self-evaluation measure the student's knowledge and experience in: technical, behavioral, and contextual competences.

The exams have a comprehensive and a formative section. The comprehensive section of the exam consists of one hundred objective multiple-choice questions; each question is related to a technical, behavioral, or contextual competence. The exams are taken in a computer lab with a two hour time limit. The accumulated data only indicates if the answer is right or wrong. The formative section considers class participation and the project development; both are evaluated with a grade. Students are also provided with guidance to improve their documents. Additionally, class participation is evaluated continuously throughout the course. It is directly related with the project management deliverables: constitution act, declaration of scope and the plans of scope, time, cost, quality, risks, human resources, communications and acquisitions. Students must present formal evidence as: minutes of the group meetings, rough drafts, minutes of the meetings with the group monitor, and proposals of change control.

All the evaluations and management deliverables are organized according to a timeline and are structured in keeping with the knowledge areas and the project life cycle.

Each student group must orally present their project's final results; the group must prepare, structure, and coordinate the individual interventions for the oral presentation. The presentation is public and open to students, professors of the Project Management Department and university faculty in general, *stakeholders*, industry managers, members of local and regional government, and citizens that live where the projects could be located. The presentation is a component of the final grade, and also a way to develop student communication skills.

IV. Data analysis

Data description

The study group consisted of the 43 students who took the project management course in 2011. For each one, a number of characteristics were registered (see Table 2. Students' characteristics).

Table 2. Students' characteristics

Students' characteristics
Age
Gender
Semester of study
Number of credits
Student performance
Cumulative grade point average

Where number of credits corresponds to the number of instructor led weekly class hours; semester of study (the undergraduate program usually lasts 10 semesters); student performance measured as the ratio of approved credits to the total number of credits enrolled; and cumulative grade point average is the average of the student's grades over his/her studies.

Figure 2 illustrates some descriptive statistics for each of those characteristics. The number of males and females attending the course is almost equal, and their ages range between 20 and 25 years. Also, more than 87% of the students are in their senior semester, and 64.5% of the total are enrolled in more than 20 credit hours of study; by contrast, the average number of credits for an undergraduate student is 21 per semester. The performance level of 86% the students was above 70%, with almost half of the students obtaining between A- and A+.

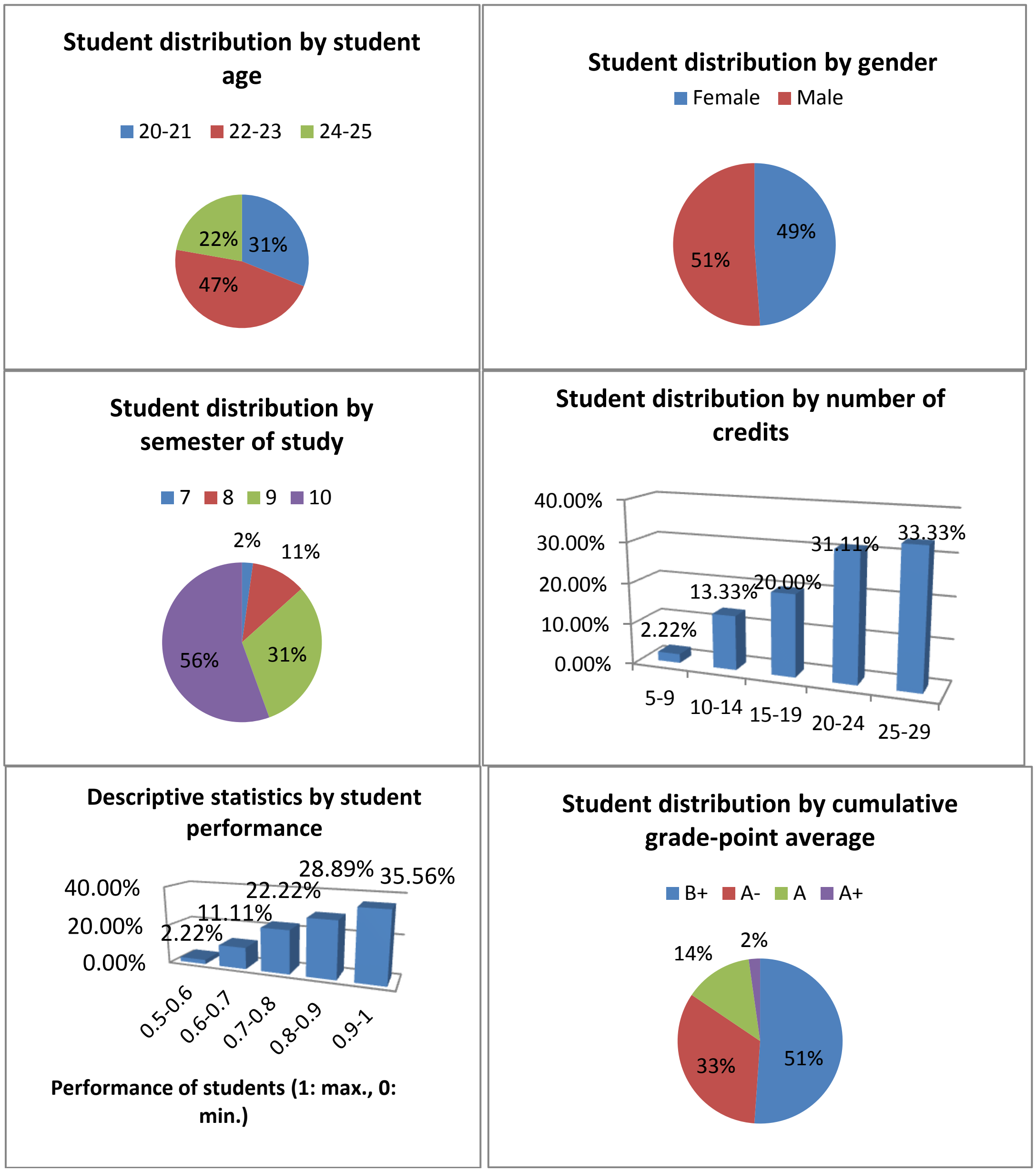

Figure 2. Descriptive statistics of students' characteristics

Furthermore, data from the evaluation of the students' competences was collected. This data corresponds to the students' self assessments (initial and final) and the exams administered during the course (1 to 5). For all of these evaluations, three types of skills were measured: technical, behavioral, and contextual.

To analyze the results of the PBL methodology, two new variables were defined:

ΔSA: Self-assessment variation; that is, the difference between the final self assessment and the initial self assessment.

ΔEV: Exam variation; that is, the difference between the final exam and the initial exam.

Both the self-assessments and the exams are measured on a 10-point scale, with 10 being the maximum score.

Data analysis and results.

The objective of this analysis is to demonstrate, based on statistical evidence, that the PBL methodology applied to this case study had successful results. The data was analyzed using STATA 11. At first, some initial evidence was obtained based on the descriptive statistics analysis, Figure 3.

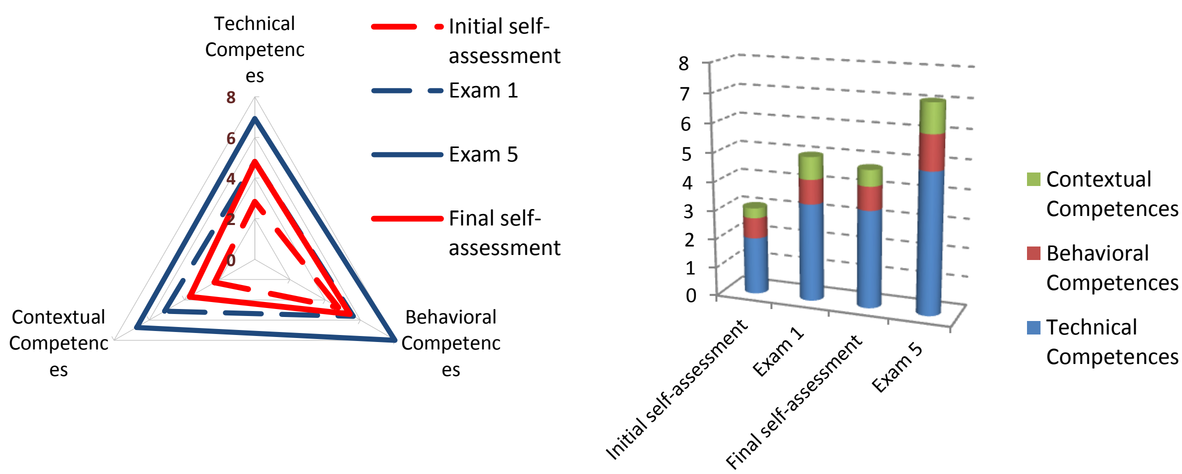

Figure 3. Descriptive statistics of students' competences

It can be seen from the graphs that the students improved their competences substantially in the three evaluated areas: technical, behavioral, and contextual. Table 3 shows the averages for each evaluation in these three areas of competences.

To test if the results in the descriptive analysis are statistically significant, mean comparison t-tests were performed. In every case, the null hypothesis was the equality of the means.

A comparison between the initial and final self-assessment for each area of competence was made. The p-value obtained indicates the rejection of the null hypothesis, which in this case means that the final self-assessment average is greater than the initial average for each area of competence. The same result was found when the t-test for the initial and final exams was performed: the p-value obtained indicates that the final test was greater than the initial one in technical, behavioral, and contextual competences. The results from this case study show that there was an improvement in the students' competences that could be explained by the application of project-based learning methodology.

Comparisons between the self-assessments and the exams were also run. The results indicate that the initial exam average score in the three types of student competence was statistically superior to the initial self-assessment score average. This also held true when comparing the final self-assessment and the final test. This result demonstrates that students are extremely self-critical, possibly explained by their immaturity and professional inexperience.

Table 3 reveals that the average self-assessment variation (ΔSA) and exam variation (ΔEV) are apparently the same. This hypothesis of mean equality was confirmed by obtaining a p-value close to 1 when comparing technical and contextual competences, and was only rejected in the case of the behavioral competences.

The professional training received by the students during their engineering studies has made them aware of what they have learned and how much they have improved in the technical area. In the case of the contextual competences, due to the fact that most of the students have already had a pre-professional job experience, they have an understanding of how the professional environment works. Consequently, they measure the improvement with some certainty. On the other hand, the behavioral competences require the development of a continuous interpersonal relationship. The students have not had enough experience, making it difficult for them to compare their interpersonal competences and measure their progress with precision.

Table 3. Initial and final self-assessment and tests: t-test results

	Final self-assessment		Initial self-assessment		Two-tailed significance
Technical competences	4.86	(1.8)	2.86	(1.46)	0.0000
Behavioral competences	5.43	(1.98)	4.75	(1.12)	0.0147
Contextual competences	3.65	(1.895)	2.3	(1.08)	0.0001

	Final Exam		Initial Exam		Two-tailed significance
Technical competences	7.44	(1.08)	4.82	(1.42)	0.0000
Behavioral competences	8.49	(0.95)	5.61	(2.39)	0.0000
Contextual competences	7.18	(1.41)	5.12	(1.65)	0.0000

	Initial Exam		Initial self-assessment		Two-tailed significance
Technical competences	4.82	(1.42)	2.86	(1.46)	0.0000
Behavioral competences	5.61	(2.39)	4.75	(1.12)	0.0305
Contextual competences	5.12	(1.65)	2.3	(1.08)	0.0000

	Final Exam		Final self-assessment		Two-tailed significance
Technical competences	7.44	(1.08)	4.86	(1.8)	0.0000
Behavioral competences	8.49	(0.95)	5.43	(1.98)	0.0000
Contextual competences	7.18	(1.41)	3.65	(1.895)	0.0000

	ΔSA		ΔEV		Two-tailed significance
Technical competences	2.353	(0.219)	2.347	(0.2153)	0.9886
Behavioral competences	1.148	(0.159)	2.609	(0.37)	0.0015
Contextual competences	1.68	(0.2845)	1.909	(0.25)	0.5893

The values are mean (SD)

It was also interesting to identify which IPMA competence elements (described in table 1) improved. To identify those elements that show statistical evidence of improvement, a mean comparison t-test at 1% significance level was performed. In the following order: creativity, teamwork, parties involved, project management success, and project organization are the competences that improved the most; whereas project timing and phases, permanent organization, scope and deliverables, business, values appreciation, openness, and program orientation are the ones that improved the least. The remaining competences did not show any statistical evidence of improvement or decrement.

Correlation analysis was used with the objective of evaluating if there was any relation between the students characteristics and the self-assessment or exam scores. Strong correlations were not found.

Additionally, the analysis shows that technical skills are positively correlated, in a moderate way, with cumulative grade-point average and student performance. This could be explained considering the fact that most of the courses the students have taken during their studies are technical and the cumulative grade-point average gives the central tendency of the grades they have obtained in the subjects. Behavioral and contextual skills are a different matter, and these do not show any relation with any of the student characteristics.

Table 4. Correlation matrix

	Age	Male	Grade-point Avg.	Number of credits enrolled	Semester of study	Student performance	Technical competences
Age	1.000	0.206	-0.588*	0.096	0.064	-0.762*	-0.357*
Male	0.206	1.000	-0.099	-0.031	-0.242	-0.143	-0.080
Grade-point Avg.	-0.588*	-0.099	1.000	-0.418*	0.307*	0.866*	**0.608***
Number of credits enrolled	0.096	-0.031	-0.418*	1.000	-0.308	-0.327	-0.314*
Semester of study	0.064	-0.242	0.307*	-0.308*	1.000	0.272	0.408*
Student performance	-0.762*	-0.143	0.866*	-0.327*	0.272	1.000	**0.579***
Technical competences	-0.357*	-0.080	**0.608***	-0.314*	0.408*	**0.579***	1.000

*Correlations significant at 0.01

Self-assessment variation (ΔSA) and exam variation (ΔEV) are also subjected to a correlation analysis; however, they did not show any significant correlation with any of the student characteristics.

In order to determine a relation of causality, a multiple linear regression was used, where the dependent variable was (ΔSA) or (ΔEV) and the explanatory variables were the observable student characteristic of Table 2. There was no evidence of causality in the results.

<u>Alternative statistical approach for future research</u>

In this study, the performance of students' competences was observed across time, which can be considered panel or longitudinal data. Given that the goal of the study is to analyze the impact of the PBL methodology over the variation of the competence performance (ΔEV), the Fixed-effects technique was considered more suitable. This technique was the first option considered in this research; however, the lack of a control group was an inconvenient. From the equity in education point of view, it was not possible for the industrial engineering program to offer two versions of the course (with and without the PBL methodology) in its curriculum. Nevertheless, the use of the Fixed-effects technique is highly recommended for future research in this type of analysis, in cases where a control group set is feasible.

VI. Conclusions

The case study results provide evidence of improvement in the student competences when the PBL approach was used in this undergraduate project management course. To support this conclusion, mean comparisons were performed which gave strong statistical evidence that student's technical, behavioral, and contextual competences at the end of the study period were enhanced.

Additionally, it was shown that when the students self-assess their competences, they hold themselves to a higher standard than the course professor. This could be attributed to a lack of maturity and lack of professional experience that would allow them to properly evaluate their own skills.

Even though they are overly critical when judging their competences, they did perceive how much they had improved in the areas of technical and contextual competences. On the other hand, they could not make a precise judgment on how much they improved in their behavioral skills. This is consistent with the IPMA model, which in its initial level of certification (level D) gives more importance to the technical competences.

Another interesting result after applying a t-test for mean comparison, was that for all 46 competences described in Table 1, the ones that the students improved the most on were: creativity, teamwork, parties involved, project management success, and project organization; whereas project timing and phases, permanent organization, scope and deliverables, business, values appreciation, openness, and program orientation are the ones that improved the least. The results also show that project closure decreased. The rest of the competences did not show any statistical evidence of improvement or decrement.

Moreover, a correlation analysis was performed, finding that technical skills are moderately correlated with the cumulative grade-point average and student performance. Regarding the behavioral and contextual skills, no correlation with any other student characteristic was found. When a multiple linear regression was performed, no evidence of causality among the variables was found. In cases where a control group could be established, a Fixed-effects technique is recommended.

In general, the experience has shown that oral presentations help students learn how to present information in a clear, concise, and informative manner, and to discuss the relevant conclusions of the work.

The use of PBL in the project management undergraduate course has highlighted the potential of the methodology as a tool to improve all three student skills. Although a definitive procedure is not recommended based on this single case study, it can be concluded that PBL is an efficient educational tool, useful for the future professional development of university graduates.

As future steps of this research, this PBL approach should be applied to different undergraduate courses and realities, to prove its robustness.

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