International Journal of Engineering Education Vol. 32, No. 2(B), pp. 894–904, 2016
Printed in Great Britain

0949-149X/91 $3.00+0.00

Learning Project Management Skills in Engineering through a Transversal Coordination Model*

ANA GONZÁLEZ-MARCOS
Department of Mechanical Engineering , University of La Rioja, c/ San José de Calasanz 31, 26004 Logroño, Spain.
E-mail: ana.gonzalez@unirioja.es

FERNANDO ALBA-ELÍAS
Department of Mechanical Engineering, University of La Rioja, c/ San José de Calasanz 31, 26004 Logroño, Spain.
E-mail: fernando.alba@unirioja.es

JOAQUÍN ORDIERES-MERE
Department of Industrial Engineering, Business Administration and Statistics, Polytechnic University of Madrid, c/José Gutiérrez Abascal 2, 28006 Madrid, Spain. E-mail: j.ordieres@upm.es

JAVIER ALFONSO-CENDÓN
Department of Mechanical, Computing and Aerospace Engineerings, University of Leon, Campus de Vegazana s/n, 24071 Leon, Spain.
E-mail: javier.alfonso@unileon.es

MANUEL CASTEJÓN-LIMAS
Department of Mechanical, Computing and Aerospace Engineerings, University of Leon, Campus de Vegazana s/n, 24071 Leon, Spain.
E-mail: manuel.castejon@unileon.es

This paper presents an innovative project management teaching approach to complement technical concepts with competences in the area of human skills. In the proposed model, the authors decided to develop a project-based and collaborative learning model combined with a transversal coordination between the same subjects in different engineering degree programs, considering the different curricula of each degree involved. This approach, among other things, allows the student to develop group competences like teamwork and communication, and to implement, in scale, the professional skills that should be deployed by a project manager, like leadership, negotiation and team management.

Keywords: engineering education; project management; technical skills; human skills; transversal coordination model

1. Introduction

The traditional way of measuring project success is the so-called 'iron triangle' of time, cost and scope [1]. However, there is no doubt today that project success cannot be attained with only a technical ('hard') skill set. Thus, although the project may be delivered within the agreed time, budget and scope, it will probably not be considered to be successful if attention has not been given to the needs and expectations of a diverse range of stakeholders [2].

Because project outcomes are achieved through people using knowledge, creativity and often technology, human ('soft') skills are as necessary as technical skills in the management of projects [3–5]. Communication, teamwork, organizational effectiveness, leadership, flexibility, creativity, problem solving and decision-making, etc. are skills required to manage people and teams and get the best out of them. There are even authors, like El-Sabaa [6], who indicate that human skills have relatively more influence than technical skills on project management practices.

Even though human skills are acknowledged as important for project management, the education offered in engineering degrees concentrates mainly on the control aspects of projects, i.e., the technical skills. It is recently that authors have started to discuss how to teach this discipline in higher education Thus, Pant and Baroudi [7] argue the necessity of a more balanced approach between technical and human concepts to enhance project management education. Clark [8] discusses the skills required for an effective project manager, as well as the analysis of four approaches at the M.Sc. level to develop these skills. Barron [9] discusses the difficulty of learning effective project management skills and suggests that there is a way to teach project management through properly designed assessment. In the same way, Sense [10] emphasizes that project learning and the learning of behaviors that will lead to success are most appropriately pursued through the creation of a suitable environment.

The teaching and learning of project management has grown in interest and popularity [11–13] and there are some practical approaches to the teaching of project management. For instance, Abernethy et al. [14] describe a specific experimental approach for information technology students. Authors argue that project activities must mirror the real world for

* Accepted 1 September 2015.

information technology students to learn what needs to be done in industry projects. More recently, Cobo-Benita et al. [15] proposed a teaching approach that is based on the 'learning by doing' paradigm in order to enable students to acquire technical knowledge and to develop some human skills, such as conflict resolution, complex problem-solving and decision making.

This work presents an innovative teaching model that aims to stimulate the learning of both technical and human skills by means of project-based and collaborative learning, combined with a transversal coordination between the same subject (''Projects'' and ''Technical Office'') in four different engineering programs: Industrial Engineering M.Sc. and Technical Industrial Engineering B.Sc. in three areas of specialization (Mechanics, Electricity and Electronics). The proposed approach was designed to provide a learning environment where:

- A more realistic framework is established because companies can negotiate how to collaborate and obtain mutual benefits.
- Students are involved in real-world engineering projects, which provides authenticity and require students to use academic and technical knowledge.
- Students are forced to adopt a more active role since they are the ones who must develop a project within given time and specifications.
- Acquisition of teamwork abilities and human skills, such as communication or negotiation, are promoted.
- Professional skills that should be deployed by a project manager are implemented in scale.
- A competitive, collective spirit is encouraged.

Nowadays, this learning framework is being implemented at the University of La Rioja. Currently, 97 students from four different degree programs participate in this model. In the four academic years during which the model was completely implemented (2007–2008, 2008–2009, 2009–2010 and 2010–2011), students' anonymous surveys indicated that the experience helped them to face a complex real world project, as well as to develop their teamwork skills.

One educational approach that has proven to be an excellent method for developing new forms of competencies [16], as well as encouraging students to engage in learning activities, is project-based learning (PBL). PBL is defined as a teaching model in which students, organized in groups, develop projects [17]. In turn, projects are defined as complex tasks that are based on challenging questions or problems that involve the students' problem-solving, decision making or investigative skills and culminate in realistic products or presentations [18, 19]. PBL includes teacher facilitation, but not direction [20], cooperative learning, reflection and incorporation of professional skills [21].

On the other hand, collaborative learning is based on the idea that learning is a naturally social act that occurs during communication among participants [22]. During collaboration, humans interact and employ self-critiquing, inquiring and arguing skills, which foster knowledge building [23].

This method enacts an integrative way of doing from the educational point of view. It is fully based on trackable evidences that are related to the exhibited project management competences from the participants. As it works per phase and role, longitudinal information can be derived per participant as long as he or she is involved in the experience.

Finally, as far as competence-learning paths can be derived from individual behaviours, it is possible to realize how effective the strategy designed by teachers becomes or which is the effectiveness of different levels of feedback, etc.

All in all, we strongly believe that it brings new information levels for all the stakeholders, in addition to its basic target of fostering the participant's competences.

The generalization capabilities of putting together different students degrees, with different roles and responsibilities also contributes to the global understanding of the working life, which is an additional positive factor this method fosters against the classical course oriented approach

It must be noted that there is a fine-line that separates cooperation and collaboration. In the former, each person is responsible for a portion of the task and coordination is only required when assembling partial results, whereas in the latter, participants work together in a continuous attempt to solve a problem.

The rest of the paper presents the definition and development of the proposed model. The second section provides an overview of the methodology chosen and Section 3 is dedicated to an analysis of the implementation details. Finally, experimental results and conclusions about the learning approach are discussed.

2. Organization of the proposed learning model

Since solving complex engineering problems requires higher levels of human-human interactions (i.e., a strong support of collaboration and multi-perspectivity) [23], and PBL also enables learners to develop their collaborative skills [24], a project-based and collaborative learning approach was

adopted. Furthermore, a transversal coordination model involving the same subject in four different engineering degree programs was introduced in order to create a more realistic context. Finally, the different curriculum of each degree program involved was considered with greater attention given to the technological aspects of Technical Industrial Engineering B.Sc. (TIE) and management in Industrial Engineering M.Sc. (IE).

In the proposed model, unlike traditional models, there is a project sponsor/customer (the instructors team) that requests the assistance of two consulting companies (teams of students of IE) that, under competitive tendering, must prepare an offer (the real-world project) to meet their needs. Given the nature of the proposed project, it is quite likely that these companies require the participation of other specialized companies (teams of students of TIE) to solve the customer's problem.

Each of the companies created must elect or appoint a project manager (PM), who is responsible for the internal organization of his/her business. Also, a few IE students are transferred to the TIE teams, where they perform as business managers (BM). It is interesting to place these students in this role because this provides an opportunity for them to practice the management tasks that they will be expected to perform at their level of training. Furthermore, these students can guide the members of their groups (TIE) on matters for which the members have yet to receive any training when the course begins. Figure 1 illustrates the configuration of the transversal coordination model that is proposed.

PMs of the consulting companies are responsible for starting the negotiations with each of the specialized companies in order to subcontract parts of the project. To give more meaning to the negotiations, each consulting company is free to talk with each specialized company. In turn, all specialized companies are free to talk among themselves. It becomes clear that, with the existence of different organizations involved in the project, the management of these relationships requires a more detailed documentation of agreements and deliveries, comments, etc.

The consulting companies—the only valid agents for the customer—are also responsible for the integration of the subcontractors' work. Thus, the technical and economic offer must be unique and integrated. Regarding the monitoring and controlling activities that IE groups should perform, it may be noted that if a subcontractor's work does not meet the customer's quality standards, the consult-

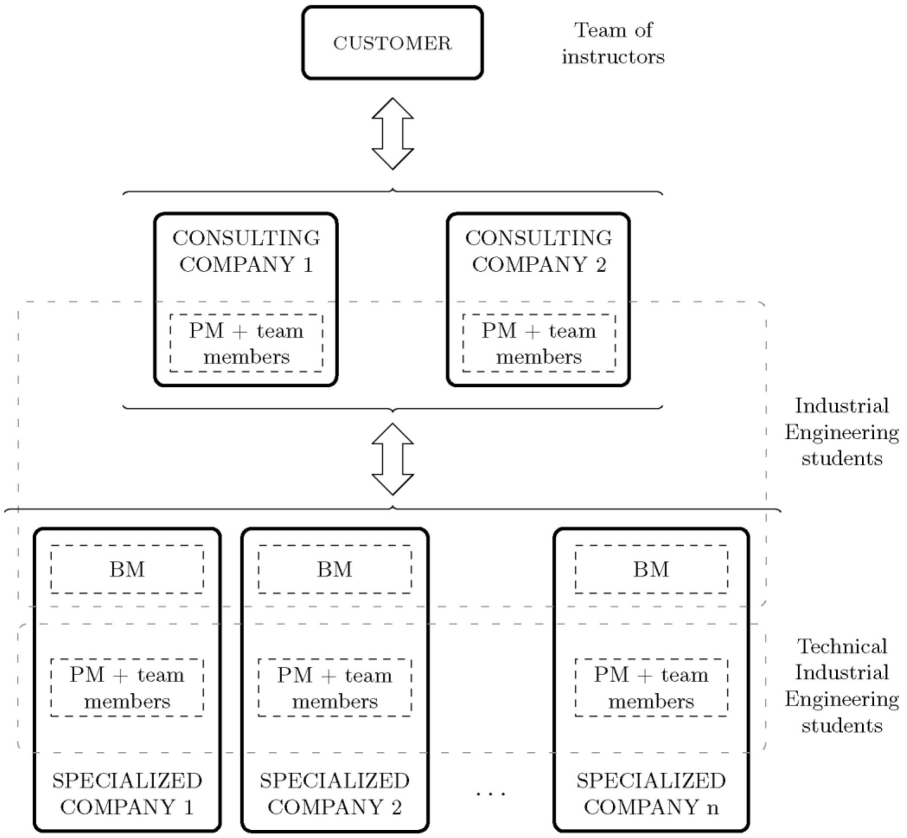

Fig. 1. Configuration of the transversal coordination model.

Table 1. Student workload expressed in time

Activity	Estimated student work time in hours
Lecture and class discussion	15 (in-class sessions) + 24 (reading)
Software seminar	6 (in-class sessions) + 3.5 (individual work)
Negotiation and project development	7.5 (in-class sessions) + 65 (out of class work)
Oral presentation	0.8 (in-class work) + 1.5 (out of class work)
Exam	3 (test) + 20 (self-study)
TOTAL	146.3 (32.3 in-class effort + 114 personal effort)

ing company should step in and complete such work, regardless of the academic consequences for the TIE group that arise as a result of poor quality of their work.

In summary, students work collaboratively as they would in a real context. The objective of the team project is to promote team and collaborative skills by concentrating on a common task.

Since the educational effort is not engaged in passing a final exam, but is directed to students' ''learning by doing,'' the organization of the course revolves around the practical activities, leaving the logical sequence of teaching of theory subordinate to it. That is, the logical progression of lessons is ''sacrificed'' to serve, if possible, the development needs of the practice work.

In accordance with ECTS criteria, the time required to complete the activities foreseen was estimated (see Table I), assuming a duration of 15 weeks per course. Credit allotment for each involved course is six ECTS credits and the University of La Rioja assigns a workload of about 25 hours per ECTS credit. Thus, with a safety factor of 2.5%, the student workload was estimated to be 146.3 hours.

2.1 Description of the student roles

The assignment of concrete roles to individuals is one of the ways to make them interdependent as a means to encourage collaboration [25]. Furthermore, the assignment of responsibilities and tasks to roles is a common practice in real projects. This provides a way of training future professionals in the social skills required in their work.

(1) Project manager (PM)

The project manager is responsible for:

- Planning, controlling and monitoring all project activities.
- Managing the resources associated with the project. Internally, the PM organizes and develops the team to build an effective project team. Externally, the PM is responsible for dealing with the consulting/specialized companies and ensuring that the project team interacts with them in a collaborative manner.
- Representing the organization in dealing with the sponsor.
- Documenting the project meetings team performance (by means of a confidential report in which the PM scores the work achieved by each team member) and subcontractors' performance on a weekly basis.
- Formally closing each phase of the project and ensuring that the objectives have been achieved and the project meets the customer's expectations.

According to their responsibilities, project managers have the authority to apply organizational resources to project activities (i.e., assign responsibilities and make decisions).

(2) Business manager (BM)

The business manager is responsible for:

- Representing the organization in dealing with the consulting companies. This responsibility includes negotiating, drafting and signing the contract, depending on the agreement reached.
- Planning, controlling and monitoring all project activities.
- Guiding team members in areas where they still have received no training when the course begins (e.g., organization of the project document).
- Documenting the team performance (by means of a confidential report in which the BM scores the work achieved by the team project as a whole) on a weekly basis.
- Formally closing each phase of the project and ensuring that the objectives have been achieved and the project meets the customer's expectations.

(3) Team member (TM)

Each team member is responsible for actively participating in the project development to meet project requirements. More specifically, each team member is required to:

- Participate in situation analysis and problem-solving activities.
- Complete assigned tasks on time and with the required quality.

- Collaborate with other team members and contribute to teamwork and morale.
- Provide weekly feedback on the actual time spent working on assigned tasks to the project manager.

2.2 Sample projects

Although different kind of projects could be selected for the adopted approach, they must fulfill the following characteristics: (1) they should allow the involvement of students with different backgrounds and areas of specialization and (2) teachers should be able to support students during the project development. For example, some of the projects proposed to the students include hazardous and non-hazardous waste management, biomass power plants, etc. These projects were complex enough to require a project organization structure. Furthermore, the team of instructors had previous experience on them, which facilitates the students' guidance and support.

2.3 Course assessment plan

To be consistent with the emphasis on practical work, the weight of the exam (40% of the final mark) is less than the practical evaluation (60% of the final grade).

The assessment of the acquisition of knowledge (theory) involves the use of tests. The assessment of the acquisition of skills and the ability to apply acquired knowledge (practice) concentrates on the different scenarios of negotiation and the agreements reached or not reached. It is clear that the more resources that are mobilized and appropriately coordinated, the greater will be the efficiency and the quality of the final work. That is, the practical work will be assessed by the consortium established and the management of the project team (group of students working as a team), as well as by the quality of the solution provided. In summary, the following topics are evaluated:

- Management performance (agreements reached between companies, communication strategies, teamwork, organizational effectiveness, flexibility, leadership, etc.).
- The degree of development of the proposed solution and the customer's satisfaction.
- The quality of the required documents:
  - Technical reports: feasibility studies, best available techniques, project monitoring, etc.
  - Contracts governing the relationship between IE and TIE groups.
  - Project document. According to the Spanish standard UNE 157001 [26].
- The quality and professionalism of the oral presentation/defence of the project.

According to the different nature of the practical aspects to be evaluated, a rubric has been designed ad hoc for this experience. The different learning aspects are identified (project organization and planning, project products, communication, negotiation, teamwork, leadership, flexibility, problem solving and decision-making) and four levels of performance are described (excellent, good, satisfactory and unacceptable) to limit teacher subjectivity. Each learning aspect is assessed by at least one form or piece of evidence, for which different weights are defined according to the performed role (PM, BM or TM).

Because both the individual's contributions and the group's contributions will be accounted for, students do not fear being paired with less motivated students and losing control of their grades. Instead, this increases a student's motivation to work in a group setting. Furthermore, to encourage a greater sense of involvement and responsibility, peer assessment was also included. Hence, the practical mark is assigned by a combination of different methods, which are weighted as follows:

- 70–75% teacher assessment (50% individual student evaluation, 20–25% group assessment).
- 25–30% peer evaluations.

Finally, it should be noted that in order to harmonize the different possibilities that the legal framework gives students, especially if they claim regulatory aspects related to attendance at non-compulsory classes, another course model was established besides the described model. In this case, each student must develop a project (practical work with a weight of 10% of the final mark) and pass a comprehensive written exam at the end of the academic year (90% of final grade).

3. Development of the learning experience

Although the methodology and the project proposal is presented at the beginning of the course, due to registration deadlines, the first two weeks are used to configure the companies, define the specialized companies profile and designate the PM and BM.

After that, consulting companies must define the scope of the project (the customer requirements are vague) and identify those project needs that can best be met by acquiring products or services outside of the project organization. Meanwhile, specialized companies concentrate on strengthening their specific profile to be able to offer the best services to their potential customers.

By the fourth week of the course, approximately, consulting companies have already prepared their procurement documents and are able to issue invitations for bids from potential subcontractors. Nego-

tiations, which take place during one and a half weeks, clarify the requirements of the requested services (scope, deadlines, budget, quality, etc.) so that a mutual agreement can be reached prior to signing a contract. From the specialized company point of view, the PM may be present during negotiations to provide assistance, but the crucial role during contract negotiations is that of the BM. These industrial engineering students are the principal persons responsible for negotiating the best terms for their companies. It is important to note that BMs are classmates of the consulting companies' PMs and, therefore, have similar academic backgrounds and levels of maturity.

The use of subcontractors provide an opportunity to utilize PM and BM skills in negotiations because, generally, the organization carrying out the project and the subcontractor working on the project have conflicting interests. The parent organization's objectives are to get the deliverable at the lowest possible cost and as soon as possible. The subcontractor's objectives are to produce the deliverable at the highest possible profit and with the least effort. Moreover, it is almost indubitable that the two parties will have significantly different ideas about the exact nature of the deliverable, itself.

Once the contracts are signed, established consortiums work to accomplish the project's objectives within the available resources and time. The deadline for the global project document is the second to last week of the course and the oral presentation/defense takes place during the last week of the course. After this presentation, there is also a session to jointly review the project's execution by the parties.

It must be kept in mind that the contract performance must be monitored and reported regularly through the project development stage and, when needed, appropriate changes and corrections should be made. In fact, while project work is being performed, a change request issued by the customer will require a revision of the project scope, plan or deliverables not only by the consulting companies, but also by the specialized companies. Under these circumstances, it is possible to observe and evaluate group competences, such as team adaptability, creativity and flexibility, problem solving and decision-making, i.e., how teams are able to manage the requested changes.

Every week, each project team holds a progress meeting for half an hour to review performed tasks and to agree on the next activities according to the plan. The PM is responsible for planning, conducting and recording the meetings, and the limited time available for the weekly team meeting reinforces the need for skills in conducting effective meetings, such as analysis, communication and leadership. On the other hand, these meetings enable teachers to assess the team's performance, as well as to observe how conflicts are managed and decisions are reached, etc.

As the person who is responsible for managing the project team, the PM is also required each week to appraise each team member's performance based on his/her attitude, work achieved and individual, reported working hours. Thus, the PM is encouraged to observe, analyze and interact with team members as a means to foster the skills required to manage the project team (communication, conflict management, negotiation, leadership, etc.).

BMs are also required to report the work carried out each week, the TIE team performance, as well as problems encountered and decisions adopted to solve them. Since these students belong to different degree programs, this is an excellent way to contribute to group cohesion.

During the process, the team of instructors plays two different roles:

- A customer who is ready to make decisions when required (e.g., changes in scope).
- An external consultant who provide clarifications and recommendations from a technical point of view.

In order to develop the proposed approach, the web-based Project Portfolio Management (PPM) software Project.net (http://www.project.net) was used. This software is a collaborative multiuser Web 2.0 environment which provides some collaborative tools (blogs, wikis, forums, etc.) allowing blended learning for the theoretical and individual's work aspects. Moreover, it provides project management tools for planning and monitoring of not only the expected deliverables and the achievement of the goals but also the progress made on learning as established in the defined rubric.

Finally, at the end of the course, students are encouraged to complete an online survey to gather anonymous feedback. This survey contains 5-point Liker scale questions (from 1 for "strongly disagree" to 5 for "strongly agree") to provide useful statistical feedback, as well as open-ended paragraph questions to gain valuable insight (e.g., lessons learned, acquired skills, and strengths and weaknesses of the model).

4. Results

Although students could choose between two learning models, most opted for the proposed approach because they saw an opportunity of learning and living new experiences that they perceived to be valuable and useful for their professional lives. Indeed, after the development experience, students

defined the learning experience as challenging and very difficult, but also very important and valuable because they were able to see what engineering project management really is about.

In order to illustrate the evaluation results according to the defined rubric [27], Figure 2 summarizes the performance assessments of the following learning skills for the academic year 2010/2011 (the red line in the figure indicates the pass/fail score):

- S01. Project organization and planning
- S02. Project products
- S03. Communication
- S04. Negotiation
- S05. Teamwork
- S06. Leadership
- S07. Flexibility
- S08. Problem solving and decision-making

Boxplots are used to depict the evaluation results because they are a standardized way of summarizing the distribution of data. A boxplot (also known as a box and whisker plot) is interpreted as follows:

- The box itself contains the middle 50% of the data. The upper edge (hinge) of the box indicates the 75th percentile of the data set, and the lower hinge indicates the 25th percentile. The range of the middle two quartiles is known as the inter-quartile range.
- The line in the box indicates the median value of the data. If the median line within the box is not equidistant from the hinges, then the data is skewed.
- The ends of the vertical lines or "whiskers" indicate the minimum and maximum data values, unless outliers are present in which case the whiskers extend to a maximum of 1.5 times the inter-quartile range.
- The points outside the ends of the whiskers are outliers or suspected outliers.

As shown in Fig. 2, most of the students successfully demonstrated the assessed skills. Only some TIE students failed the project products (S02), communication (S03) and/or problem solving and decision-making (S08) skills. It is worth to mention the higher level of performance achieved by IE students in most of the learning skills, which could be explained by their previous training in project management—IE students were formerly TIE students—as well as their higher maturity based on their age.

When comparing the success of students among different academic years (see Fig. 3), it is possible to observe that the implementation of the described experience had a positive influence in both the number of students that passed the course (the red line in the figure indicates the pass/fail score) and the final grades.

Finally, the student satisfaction with the proposed teaching approach is analysed. Figures 4 and 5 illustrate the students' level of satisfaction with this teaching model. When comparing responses of IE students (Fig. 4) with those of TIE students (Fig. 5), some similarities and differences were observed. Although both IE and TIE students recognize that this approach helps them to learn better, IE students were slightly more skeptical than TIE students by the end of the first year. However, after the second year, IE students' perception improved. Regarding the usefulness and importance of the experience, both IE and TIE students perceived it to be valuable and useful for their

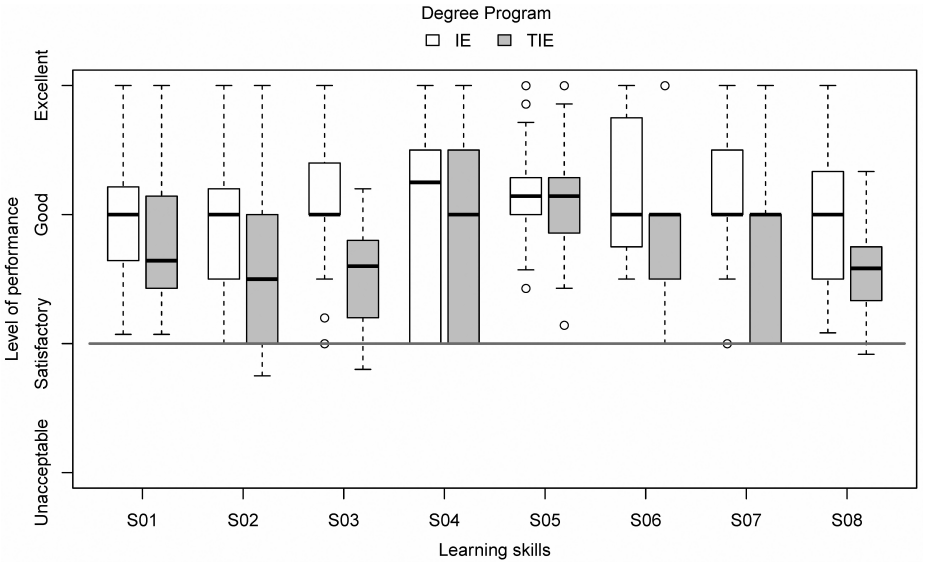

Fig. 2. Learning skills results for the academic year 2010/2011.

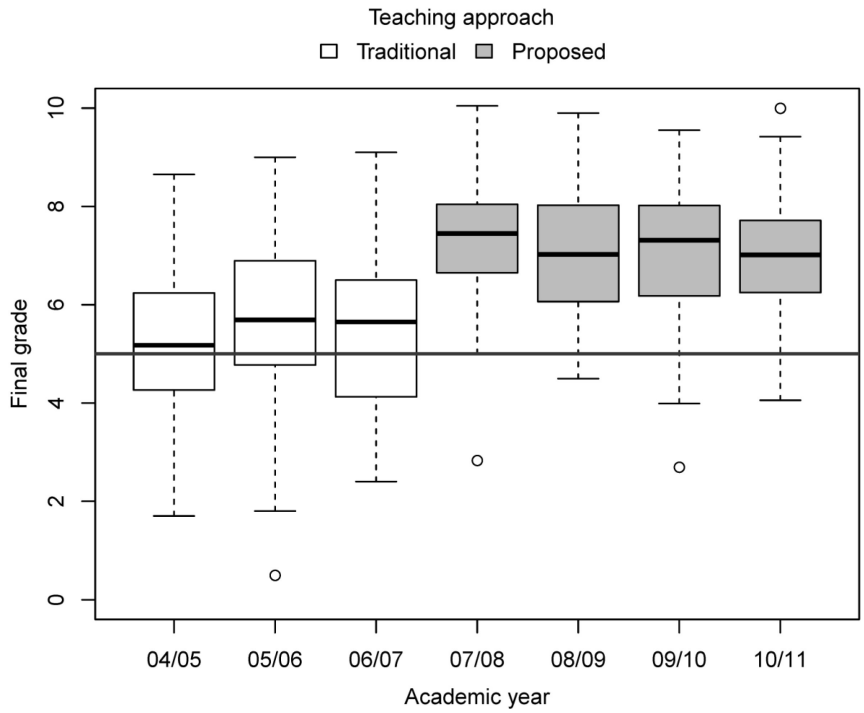

Fig. 3. Evolution of the final grades.

professional lives. It is clear that most students support the teaching model and that support scores rose among years. Indeed, the improvements implemented, such as deeper clarification of roles and responsibilities (according to the valuable feedback provided by the students), can help to explain this increment in satisfaction scores.

Based on students' reflections on project management learning, the following lessons learned were the most recurrent:

- The importance of teamwork and communication.

For most students, this was the first experience of working in a team. Thus, they were inclined to work in a "disconnected" way inside the team. However, the need to solve a complex problem with interdependent tasks promoted student interaction. In this way, decision making, conflict resolution and communications skills, among others, were put into practice. Although sometimes it was difficult, students recognized that by helping each other and resolving disagreements amicably, the whole was greater than the sum of its parts. Also, they became aware of the value of

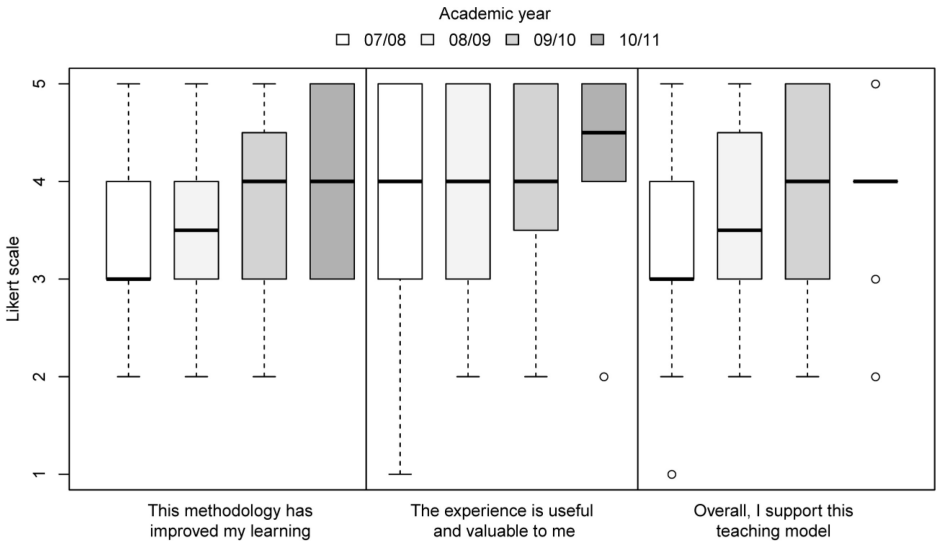

Fig. 4. Statistical distribution of Industrial Engineering students' perception of the learning experience.

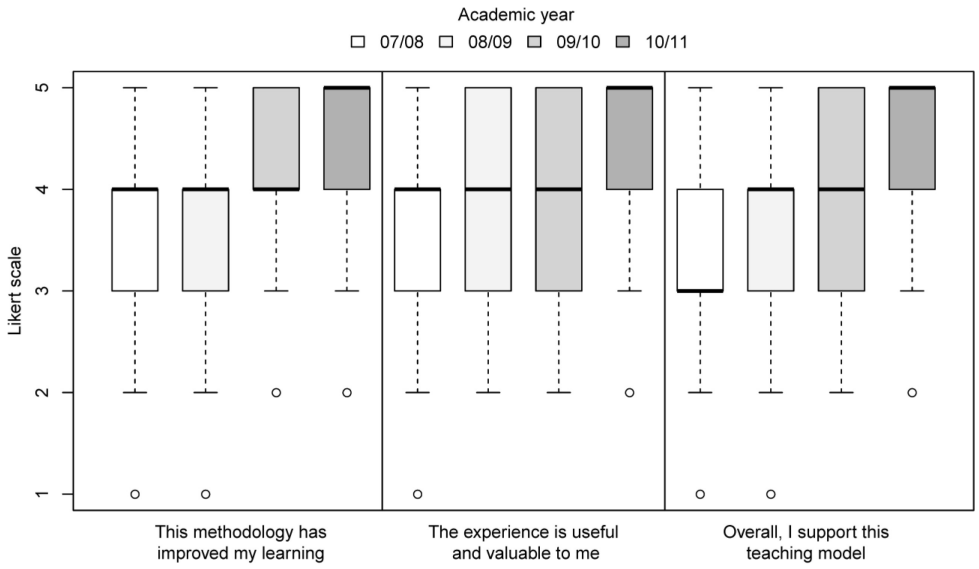

Fig. 5. Statistical distribution of Technical Industrial Engineering students' perception of the learning experience.

keeping personal issues from interfering with the functioning of the team.

- The significance of an early understanding of the sponsor's requirements to identify the work required to complete the project, i.e., to correctly define what is and is not included in the project (project's scope definition).

  Students realized that, without an appropriate project's scope definition, continuous scope changes and contract revisions were needed and accordingly, planning, monitoring and controlling the project required difficult work that sometimes did not prevent the project from being considered to be a failure.
- The need to correctly define contract terms and conditions because a contract creates a legal relationship that obligates both parties.

  The goodwill when launching the "partnership" evaporated when problems arose during project development. Changes or problems in the project put to the test the contracts, with the weak ones quickly becoming evident. Related to contracts, students also learned of the problems with oral agreements. They are inevitably difficult to prove and, typically, when it comes to a dispute, contractor and customer remember things differently.
- The importance of planning and executing according to a plan in order to accomplish the project objectives and create the required deliverables within the specified time. Due to the course duration, it was not possible to delay the project and, in some cases, a lack of planning led to delivery of projects with reduced quality standards. Fortunately, in most cases, students were able to organize and work as a team, delivering a project within the required scope, schedule and quality.

5. Conclusion

The proposed teaching model has proven to be an important vehicle for both the motivation of students who are exposed to it, and its value in learning about project management from the technical and human point of view.

This experience demonstrates that "real" projects served well in providing students with the opportunity to face the kind of problems that they may encounter during their professional lives. Thus, they could learn and reflect about project management abilities, as well as put into practice the skills necessary to identify and fill the gaps in their knowledge.

Several concerns arise from this experience. The first one is the adequate number of students in each group. The complexity of the projects makes them unachievable for small groups of students (with four or five members). Also, if a team has more than 15 members, it is more likely to contain some non-participating students and more difficult to identify them. According to the authors' experience, groups can work effectively with 10/12 members, although there is a need to identify at an early stage (and possibly fire) these resistant members. A second issue is how to adequately measure students' effort. Although students report the actual time spent working on assigned tasks on a weekly basis, they tend to overestimate the time that they devote to those tasks. Finally, the implementation of student-centered learning requires a considerable investment in time compared to those more traditional,

teacher-centered classroom activities. Therefore, there is a need for tools or mechanisms that can support teachers as they adopt new teaching strategies.

The next steps planned include the incorporation of new tools to reduce the teacher workload and the creation of geographically dispersed teams in order to bring virtual team skills to students.

Acknowledgements—The authors wish to recognize the support of the Spanish "Ministerio de Educación" through its research funding program, as part of this work was supported by its Grant EDU 2012-31080.

References

1. R. Atkinson, Project management: cost, time and quality, two best guesses and a phenomenon, it's time to accept other success criteria, *International Journal of Project Management*, **17**, 1999, pp. 337–342.
2. L. Bourne and D. H. T. Walker, Advancing project management in learning organizations, *The Learning Organization*, **11**(3), 204, pp. 226–243.
3. K. Belzer, Project management: still more art than science, Paper online, 2001, Available: http://www.pmforum.org/library/papers/2001/ArtthanScience.pdf, Accessed 6 July 2015.
4. B. Sampson, Get with the project, *Professional Engineering*, **20**(12), 2007, pp. 41–42.
5. R. Colomo-Palacios, C. Casado-Lumbreras, P. Soto-Acosta, F. J. García-Peñalvo and E. Tovar-Caro, Competence gaps in software personnel. A multi-organizational study, *Computers in Human Behavior*, **29**(2), 2013, pp. 456–461.
6. S. El-Sabaa, The skills and career path of an effective project manager, *International Journal of Project Management*, **19**, 2001, pp. 1–7.
7. I. Pant and B. Baroudi, Project management education: the human skills imperative, *International Journal of Project Management*, **26**, 2008, pp. 124–128.
8. R. Clark, Project Management: The Key to Engineering Employability, presented at SEFI—*36th Annual Conference, Aalborg*, Denmark, 2–5 July 2008.
9. S. Barron, Assessing project management learning – how can it make a difference?, presented at *2nd Project Management Conference: Excellence in Teaching, Learning and Assessment, Bournemouth*, 15–16 September 2005.
10. A. Sense, Structuring the project environment for learning, *International Journal of Project Management*, **25**, 2007, pp. 405–412.
11. C. Berggren and J. Söderlund, Rethinking project management education: Social twists and knowledge co-production. *International Journal of Project Management*, **26**, 2008, pp. 286–296.
12. U. Ojiako, M. Ashleigh, M. Chipulu and S. Maguire, Learning and teaching challenges in project management, *International Journal of Project Management*, **29**, 2011, pp. 268–278.
13. H. L. Reif and M. Mitri, How university professors teach project management for information systems, *Commun. ACM*, **48**(8), 2005, pp. 134–136.
14. K. Abernethy, G. Piegari and H. Reichgelt, Teaching project management: an experiential approach, *Journal of Computing Sciences in Colleges*, **22**(3), 2007, pp. 198–205.
15. J. R. Cobo-Benita, J. Ordieres-Meré, I. Ortiz-Marcos and A. Pacios-Álvarez, Learning by doing in Project Management: Acquiring skills through an interdisciplinary model, presented at IEEE EDUCON 2010 Conference, Madrid, Spain, 14–16 April 2010.
16. E. Graaff and A. Kolmos, Characteristics of Problem Based Learning, *Journal of Engineering Education*, **19**(5), 2003, pp. 657–662.
17. J. W. Thomas, A review of research on project-based learning, Paper online, 2000, Available: http://www.bobpearlman.org/BestPractices/PBL_Research.pdf, Accessed 6 July 2015.
18. B. F. Jones, C. M. Rasmussen and M. C. Moffitt, Real-life problem solving: A collaborative approach to interdisciplinary learning, Washington, CD: American Psychological Association, 1997.
19. J. W. Thomas, J. R. Mergendoller and A. Michaelson, Project-based learning: A handbook for middle and high school teachers. Novato, CA: The Buck Institute for Education, 1999.
20. D. Moursund, Project-based learning using information technology. Eugene, OR: International Society for Technology in Education, 1999.
21. W. Diehl, T. Grobe, H. Lopez and C. Cabral, Project-based learning: A strategy for teaching and learning. Boston, MA: Center for Youth Development and Education, Corporation for Business, Work, and Learning, 1999.
22. J. M. Gerlach, Is this collaboration?, In Bosworth, K. and Hamilton, S.J. (Eds.), Collaborative Learning: Underlying Processes and Effective Techniques, *New Directions for Teaching and Learning*, **59**, 1994.
23. F. M. Schaf, D. Müller, F. W. Bruns, C. E. Pereira and H. H. Erbe, Collaborative learning and engineering workspaces, *Annual Reviews in Control*, **33**, 2009, pp. 246–252.
24. S. Williams van Rooij, Scaffolding project-based learning with the project management body of knowledge (PMBOK), *Computers & Education*, **52**, 2009, pp. 210–219.
25. D. W. Johnson, R. T. Johnson and K. Smith, Active Learning: Cooperation in the College Classroom, Edina, MN: Interaction Book Company, 1991.
26. AENOR, UNE 157001, General criteria for the formal preparation of the documents which constitute a technical project, *Spanish Association for Standardization*, 2014.
27. A. Fidalgo-Blanco, M. L. Sein-Echaluce, F. J. García-Peñalvo and M. A. Conde, Using Learning Analytics to improve teamwork assessment, *Computers in Human Behavior*, **47**, 2015, pp. 149–156, ISSN 0747-5632, http://dx.doi.org/10.1016/j.chb.2014.11.0.

Ana González-Marcos has been an Associate Professor of Project Management since 2010. From 2003 to 2007, Professor González-Marcos taught Project Management at the University of León. In 2007 she moved to the University of La Rioja, where she works in the Department of Mechanical Engineering. The primary focus of her research is knowledge management and knowledge discovery from data.

Fernando Alba-Elías has been an Associate Professor in Project Management since 2007 and currently works at the UR (ETSII). His research interests include project management issues, nano-coating using atmospheric plasma technology and product design.

Joaquín Ordieres-Meré has been a full professor in Project Management since 1997 and currently works at the UPM (ETSII). His research interests include project management issues, business intelligence and business analytics. He serves as reviewer for different peer-reviewed journals and is a member of the editorial board of IDMMM journal.

Javier Alfonso Cendón is PhD in Engineering by the University of Leon, Master MBA by the Polytechnic University of Madrid, Master in Renewable Energies by the University of Leon, Master in Security by University of Leon / INTECO and Computer Engineer by the University of León. He has many specialized courses in the field of engineering and communication technologies. He is PhD Assistant Professor in the area of Engineering Projects in the University of León. He has more than 20 national and international publications in the field of ICT.

Manuel Castejón Limas is an Associate Professor at Universidad de León. His research background comprehends the formulation of new data mining algorithms as well as the application of these techniques to a broad number of scientific and technical fields. His experience teaching Project Management courses encompasses 15 years. He is member of AEIPRO since 2000.