CrossMark

# Spiral and Project-Based Learning with Peer Assessment in a Computer Science Project Management Course

Arturo Jaime[1] · José Miguel Blanco[2] · César Domínguez[1] · Ana Sánchez[2] ·
Jónathan Heras[1] · Imanol Usandizaga[2]

**Abstract**  Different learning methods such as project-based learning, spiral learning and peer assessment have been implemented in science disciplines with different outcomes. This paper presents a proposal for a project management course in the context of a computer science degree. Our proposal combines three well-known methods: project-based learning, spiral learning and peer assessment. Namely, the course is articulated during a semester through the structured (progressive and incremental) development of a sequence of four projects, whose duration, scope and difficulty of management increase as the student gains theoretical and instrumental knowledge related to planning, monitoring and controlling projects. Moreover, the proposal is complemented using peer assessment. The proposal has already been implemented and validated for the last 3 years in two different universities. In the first year, project-based learning and spiral learning methods were combined. Such a combination was also employed in the other 2 years; but additionally, students had the opportunity to assess projects developed by university partners and by students of the other university. A total of 154 students have participated in the study. We obtain a gain in the quality of the subsequently projects derived from the spiral project-based learning. Moreover, this gain is significantly bigger when peer assessment is introduced. In addition, high-performance students take advantage of peer assessment from the first moment, whereas the improvement in poor-performance students is delayed.

**Keywords**  Project-based learning · Spiral learning · Peer assessment · Project management

✉ César Domínguez
   cesar.dominguez@unirioja.es

   Arturo Jaime
   arturo.jaime@unirioja.es

   José Miguel Blanco
   josemiguel.blanco@ehu.es

   Ana Sánchez
   ana.sanchez@ehu.es

   Jónathan Heras
   jonathan.heras@unirioja.es

   Imanol Usandizaga
   imanol.usandizaga@ehu.es

[1]  Dpto. de Matemáticas y Computación, Universidad de La Rioja, Ed. Vives, Luis de Ulloa s/n, 26004 Logroño, Spain

[2]  Dpto. de Lenguajes y Sistemas Informáticos, Fac. Informática, Universidad del País Vasco, UPV/EHU, P. Manuel de Lardizabal 1, 20018 Donostia-San Sebastián, Spain

## Introduction

Computer science degrees usually include a course to develop the competences related to project management (PMI 2013; ICB-IPMA 2006)—the discipline of organizing and managing resources in such a way that those resources do all the work required to complete a project within defined scope, time and cost constraints (Nembhard et al. 2009). This is the case in the computer science degrees of two face-to-face and distant universities U1 and U2. The project management courses in both universities share the general goal, most of the competences to develop, the number of credits, the level (third level) and the semester (second semester). In this paper, we present a teaching proposal, implemented in both courses, that is based on the combination of three well-known teaching methods: project-based learning (PBL), spiral learning (SL) and peer assessment (PA).

⚫ Springer

PBL is a widely spread pedagogical method where the course is designed around one or more projects. PBL is characterized by the following aspects (Thomas 2000): centrality (not peripheral to the subject), driving question (focused on problems that drive students to encounter the central concepts and principles), constructive investigation (new understanding and skills on the part of students), autonomy (more unsupervised work time and responsibility) and realism (not school-like projects). There are several experiences related to the application of PBL, specially in the context of engineering degrees (Chandrasekaran et al. 2012; Domínguez and Jaime 2010; Prince and Felder 2006; Martín et al. 2013), and particularly in project management courses (Guerrero et al. 2013; Huang et al. 2008; Cobo-Benita et al. 2010; Ivanovic et al. 2012). Those experiences highlight several benefits for students (Palmer and Hall 2011; Frank et al. 2003): motivation; production of more complex and better quality products; promotion of responsibility, engagement and independent learning; understanding of content and process; experimentation of team work with different people; and involvement in different kinds of tasks related to the professional practice. In this manner, students achieve a better understanding of the professional practice and the way of applying the acquired knowledge to real problems (Prince and Felder 2006).

SL is a learning model that suggests that the concepts of a topic are introduced at different points of time with increasing amount of detail. The premise is that a subject is not learned the first time around and the student can pick up more information in successive cycles. Initially, basic concepts are introduced without providing too many details. In each learning cycle, further details are introduced and the student can expand on his skill level by building new understanding and reinforcing the concepts learned previously (Vemuru et al. 2013). This approach is similar to the spiral model of software development (Boehm 1988) and to agile development; the latter promotes a life cycle with several iterations where each iteration gets benefits from the previous iterations, allowing reorientation and resolution of errors (Fowler and Highsmith 2001). In the courses where the SL method is applied, each learning cycle takes only a short period to be completed; therefore, students can quickly see the result of their work, and their motivation to learn remains high. This method also allows that the core knowledge and skills can be repeated in different forms (Jing et al. 2011).

PA and self-assessment refer to those activities of learners in which they judge and evaluate their own products of work and those of their peers with similar learning backgrounds (Topping 2010). PA benefits students by offering them the opportunity to observe and compare peers' works; it exposes students to solutions, perspectives, strategies and insights that, otherwise, are unlikely to see (Chang et al. 2012). PA encourages to emulate the strengths and avoid the weaknesses of other people in order to improve the students' understanding and their confidence in the subject (Søndergaard and Mulder 2012). Similarly, self-assessment helps students reflect on gaps in their understanding, making them more resourceful, confident and higher achievers. Self-assessment provides students an opportunity to look at their own work again and was also useful for identifying mistakes and reflection (Chang et al. 2012). Few studies clearly differentiate between the effects of assessing peers versus the effects of being assessed by peers. It is also suggested that further experimental and quasi-experimental studies are necessary to contrast variables outcomes for assessor and assessee, and high- or low-performance students (Topping 2010).

Our proposal consists of developing four projects (PBL). The duration, scope and difficulty of the projects are increased at the same time that the knowledge of students about project planning, monitoring and controlling (SL). Moreover, at the end of three of the projects, the student is asked to assess a set of products carried out by peers or himself (PA).

Each project has its own specification, concrete management goals (of contextual type) and behavioral competences. In addition, they cover the five phases of the project life cycle: initiating, planning, executing, monitoring and controlling, and closing. Competences that were developed in previous projects are continuously applied to reinforce them while new challenges are tackled. Skills to manage a team, relations with clients, communications, quality or acquisitions are incorporated progressively. In this way, aspects of the ten knowledge areas included in the PMBoK (PMI 2013) are taken into account. Moreover, emphasis is also put on information management and on gathering learning lessons extracted from the students after a process of reflection and synthesis.

Both the use of PBL in spiral and PA have been documented in the literature; however, we have not found any work that combines these three teaching methods. Hence, the current work has three main goals:

- Show a coherent proposal that combines PBL, SL and PA in a computing science project management course that has been successfully implemented during several academic courses.
- Analyze the influence of adding PA to PBL and SL in the quality of the projects developed by the students.
- Analyze whether there are significant differences in the application of such a combination depending on the kind of student.

In order to achieve these goals, we have considered three consecutive academic years. In the first year, PBL

and SA were used. In the two subsequent years, PA was incorporated.

We want to contrast the following hypotheses:

1. The PBL method in spiral means an improvement in the students throughout the projects that compose the spiral. Additionally, such an improvement is increased when the students participate as assessors in a PA process.
2. The combination of the three teaching methods (PBL, SL and PA) acts differently on high- and low-performance students.

## Related Work

A review of pedagogical trends for project management in universities and colleges was provided in (Geist and Myers 2007). The majority of educators agree that the course must include the use of team projects based on PBL as real world projects, simulations projects or case studies. They suggest a blend of learning techniques in order to achieve a high level of success. A recent study (Ramazani and Jergeas 2015) identifies three areas to be considered in the training and education of project management: development of critical thinking (to face the complexity of managing projects that is getting more complex everyday), leadership and interpersonal skills, and training to tackle contexts in real life. In addition, they also suggest some teaching methods to be used in such an education like case studies, project-based learning, role modeling, team working, mentorship and other active methods.

PBL has been applied in different ways to project management courses. In some cases, students carry out a unique team project (Guerrero et al. 2013; Huang et al. 2008; Cobo-Benita et al. 2010); in other cases, the project is developed individually Ivanovic et al. (2012). However, we have not found any work that proposes several projects for teaching project management. This approach (using several projects) has been applied in the first course of engineering degrees (Palmer and Hall 2011; Frank et al. 2003). PBL has been incorporated by means of three projects to a design and professional skills course (Palmer and Hall 2011). An evaluation of students perception revealed their satisfaction with the results obtained in their projects. In the experience presented in (Frank et al. 2003), the products developed by the teams were compared in the class, obtaining in this way a competitiveness component. The comparison of projects allows the students to think about the reasons for the success or failure of their projects; additionally, students examine alternatives and select the optimal solution (the basic principle of engineering). This competitiveness component also appears in (Cobo-Benita

et al. 2010), where students performed real engineering projects by teams in a project management course.

In PBL, projects might be either real or simulated (playing at managing projects). Simulation allows projects to get closer to real projects. It is a procedure to emulate the kind of work carried out in a company (Alba-Elías et al. 2014) in the framework of contractual, laboral and organizational relations, trying to approximate concepts such as cost management or human resources. The goal consists in offering a more realistic approach from the point of view of the organization, the processes and the communication (Broman et al. 2012). Moreover, it is desirable to incorporate clients. For instance, the approach of (Tynjälä et al. 2009) allows the students to work closely with clients in weekly meetings. The basic idea is that the technical orientation must come from the clients as much as possible, whereas the university is in charge of a more generic orientation (e.g., planification and report presentation). In this case, students are supervised both for clients and for university instructors. There are also some approaches that complement the standard PBL. For instance, mental maps, analogies (to increase the creativity) and round table discussions (for key technical issues) are incorporated in engineering courses with improvements in the results (Chua et al. 2014).

The spiral curriculum proposed by (Bruner 1960) has been implemented successfully in several courses of concrete degrees (Vemuru et al. 2013; Lohani et al. 2011; DiBiasio et al. 2001). The same idea was applied in the framework of an embedded systems course (Jing et al. 2011) with positive results for learning. Nevertheless, we have not found any experience that applies SL to project management courses. Some authors suggest the application of SL ideas by means of the development of several projects (PBL) of increasing difficulty. For instance, this approach was employed in basic programming courses (Vega et al. 2013) obtaining positive results related to the opinion of students about these courses, the mean grade obtained and the motivation of students to carry out their projects.

Specific simulators have been also used for teaching project management. These software tools combine the interactive study of a case with a project management system and allow students to acquire experience in management topics and learn from previous results. The simulators supply immediate answers based on the decisions taken by the user and might provide some situations that are difficult to find in the real world (Davidovitch et al. 2006, 2009; Nembhard et al. 2009). Some results about the use of these tools conclude that it is better to use them following a cooperative strategy instead of a competitive one (Nembhard et al. 2009). Additionally, it has also been observed that it is better to manually store the history of

what is happening than delegate this task to the tool; and better results are achieved when actions can be undone to recover a previous state (Davidovitch et al. 2006).

Another method that has been applied in project management courses is case studies (Cameron et al. 2012; Jewels and Albon 2009), which objective is understanding the true nature of IT projects without actually being involved in a real-life project. This method uses written descriptions of actual situations. The first task for the instructor is to find an interesting situation to study, visit the organization, collect relevant data and write a description. Students start the activity reading the case description before discussing it in class, where the instructor poses questions. The student plays the role of an involved person and has to make decisions, solve problems, meet challenges or develop opportunities. This method improves several skills: analytical, decision making, synthesis, listening, presentation and time management. However, some interesting aspects cannot be collected in the case description (e.g., economic, social or technological context). Also, the instructor's knowledge of the case is usually insufficient, limiting the depth of the discussion. This method was applied in an information systems project management course (Cameron et al. 2012). In that work, the authors propose two case studies, and they count on the protagonists of the actual situation that suggest to the students some decision points. Students evaluated positively the experience. Another positive experience with a similar course, wherein also the protagonist of the actual situation participates, was presented in (Jewels and Albon 2009).

The authors of (Boubouka and Papanikolaou 2013) suggest that the incorporation of peer assessment in a PBL is interesting to be investigated. Assessment, rather than being conducted only in the end of the course to measure the results (summative assessment), should be carried on throughout the learning process (formative assessment) (Strijbos and Sluijsmans 2010). It concerns the students that conduct the assessment as well, since while reading the work of their peers, they have the opportunity to reflect on their own work, realizing their errors and deficiencies. In this way, staged project work (Søndergaard and Mulder 2012) lends itself particularly well to integrated peer assessment. It allows feedback to be produced and digested for a project that is still in progress. Additionally, in (Søndergaard and Mulder 2012), it is mentioned that it is preferable to avoid "students grading students." Peer grading may introduce a degree of discomfort and/or an unwanted sense of competition among students (Boubouka and Papanikolaou 2013), jeopardizing the collaborative potential. Students can provide grades that are indicative but do not really count, as in the setup of Gibbs (1999).

The engineering profession uses peer reviewing extensively, as a proven quality assurance method (Søndergaard and Mulder 2012). Peer reviews find mistakes in requirements specifications, documentation and manuals—problems that no amount of testing will help to solve. For instance, in the work of (Machanick 2005), it is described an experience wherein members of a class review each other's designs from early stages of a course on data structures and algorithms. In this way, students can both play the role of the learner (when they are assessees) and the "oldtimer" (when they are assessors); moreover, the students are exposed to a style of work which promotes learning. Seeing both perspectives creates a sense of the real community wherein students will work.

## Teaching Proposal: Projects Spiral and Peer Assessment

As we have previously explained, our teaching proposal is structured around four projects that are carried out through 13 weeks and which duration, involvement and complexity are increased progressively. We will call these Projects P1, P2, P3 and P4. Projects P1 and P2 last 2 weeks, Project P3 3 weeks and Project P4 6 weeks. The number of members in the working teams is also increased progressively. Project P1 is an individual project, Project P2 is carried out by teams of two or three members, teams performing Project P3 consist of three or four students, and Project P4 is developed by teams of five or six people. The distribution of people on teams is organized by the instructor.

Table 1 shows the characteristics of the products developed in the four projects during the years of the experience. Project P1 is developed while students are making their first contact with the course. The goal of the students in this project consists in deploying a personal plan related to their involvement in the courses during the semester. The plan is completed with a viability analysis to pass the course. Projects P2, P3 and P4 share a common axis; in this way, the elements of previous projects reappear, extended and interrelated. Moreover, new elements appear, the difficulty is increased, and a more realistic context is shaped. The products to be developed in Projects P2, P3 and P4 have been simple, complete and publicly Internet-available multimedia Web systems. Since the projects are publicly available, they can be accessed by anyone; hence, the author is responsible of what he is publishing (for instance, he should not use contents without the corresponding consent, and he should care about what he is publishing). The use of complex technologies has been avoided. However, we have always tried that the developed projects allow the students to establish clear analogies with the development process in computing products. Hence, the product of Project P4 has been a multilingual Web site developed using a widespread

**Table 1** Products and management deliverables of the projects

| | Project P1 | Project P2 | Project P3 | Project P4 |
|---|---|---|---|---|
| Product | Personal schedule for the semester | 2′ video accessible via Web | Web site with 4′ video and license. It also includes 3 P2 videos and interaction form with the visitor | Multilingual WordPress Web site with license, a 4′ P3 video, several P2 videos, interaction form with the visitor and interesting links. Accordance with WAI-A and national legislations. Slides for client approval |
| Planning | Tasks: description, estimated time and execution period | | WBS, tasks: description and estimated time, deliverable identification, responsibilities, Gantt, quality features and procurements | WBS, tasks: description and estimated time, deliverable identification, responsibilities, Gantt, Quality plan, Procurement plan, Risk plan, Communication plan and Change plan |
| Monitoring and controlling | Monitoring with comparison between estimated and real times | | Monitoring and control with comparison between individual and collective estimated and real times | Monitoring and control with comparison between individual and collective estimated and real times. Monitoring and control of the different plans |
| Lessons learned | Personal list of individual lessons learned | | | Common knowledge base with lessons learned |

content manager (e.g., WordPress) that must be fully functional and be available at least 3 weeks.

In order to illustrate the kind of projects that are carried out by the students, we thoroughly explain a product example for P3. The project consists in developing a Web site that contains formative resources related to project management. The site should include two sections. The former section contains videos created in P2 by other teams (procurement). Those videos deal with five questions that were studied in P2, such as life cycle or base line. Additionally, a new video must be created by the students explaining both a concrete figure and a concrete table of PMBoK (PMI 2013). The other section of the site must gather information about the interests and characteristics of the Web site's visitor. Such an information must be determined with the help of a client including the concrete questions to be asked to the visitors. Additionally, the client helps to determine some of the Web site features, such as navigation elements, languages, Web design, mobile version and so on.

Table 1 also shows the characteristics of the main management deliverables through the four projects. These deliverables also incorporate progressively new elements or higher difficulty. This is related to the processes of PMBoK (PMI 2013) that are tackled. As it is depicted in Fig. 1, all the projects consist of significant elements of the five process groups of the project life cycle: initiating, planning, executing, monitoring and controlling, and closing. The left side graphic of Fig. 1 represents the deepness level used to deal with each process group in each project. It can be noticed that in each project the level is increased in some process groups regarding its previous project. In P4, all processes are tackled in the deepest level. In the right side of Fig. 1, the graphic represents a spiral

where the novelties tackled in each process group for each project from P1 to P4 are briefly characterized.

Table 2 shows the treatment given in each project to each one of the ten knowledge areas of PMBoK. Figure 2 shows how the complexity of the tasks associated with each area is increased. This representation is similar to the one employed in Fig. 1. It shows that in Project P4 the deepest level is used to tackle the ten knowledge areas. It also illustrates the areas wherein progresses are made from Projects P1 to P4. In summary, while students are carrying out their projects, several processes of the project management are covered either tacitly or explicitly. In Project P1, students work the basic triangle of project management: scope, cost and time. The student has to work with limited resources and really tight deadlines, while he identifies the phases of planning and monitoring, and controlling. In Project P2, students are introduced to the area of quality management and superficially to aspects of risk management, human resources and communications. In Project P3, students work explicitly the phases of initiating and closing, and they acquire a deeper knowledge in the rest of areas. Finally, in Project P4, students complete the conceptual framework tackled in the course. For instance, the integration management is incorporated dealing with the changes management. We try that students grasp that changes might come not only from clients but also from the team project or the organization where they are working.

From our point of view, it is important that students understand the necessity of properly managing the relations with stakeholders and its influence in the complexity of the computer science practice. To achieve this goal, we think that is advisable to locate the student outside the safety net of the instructor as reference and the marking system as

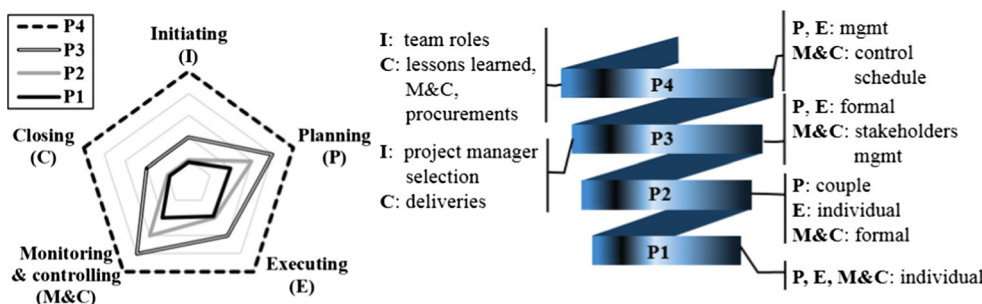**Fig. 1** Five PMBoK management process groups (I, P, E, M&C and C) in the different projects (P1, P2, P3 and P4)

**Table 2** Ten PMBoK knowledge areas covered in the different projects (P1, P2, P3 and P4)

| Area | Project P1 | Project P2 | Project P3 | Project P4 |
|---|---|---|---|---|
| Scope | Basic | Formal | Management | Contractual |
| Time | Basic | Management | Schedule monitoring | Schedule management |
| Cost | Monitoring | Control | Management | Management |
| Quality | | Monitoring | Control | Client satisfaction |
| Risk | | Monitoring | Control | Management |
| Human resource | Personal effectiveness | Collaboration | Team management | Leadership |
| Communication | With the instructor | Team | Management | Client satisfaction |
| Procurement | Syllabuses | Monitoring | Control | Management |
| Stakeholder | | | Expectations management | Client satisfaction |
| Integration | | | | Change management |
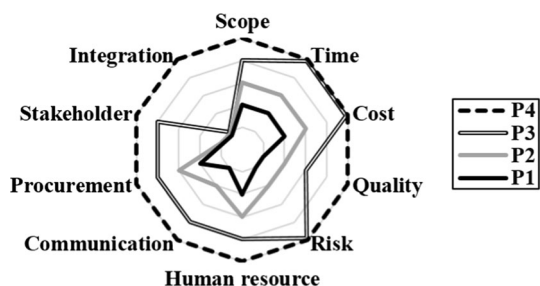


**Fig. 2** Ten PMBoK knowledge areas covered in the different projects (P1, P2, P3 and P4)

guide. This means the involvement of external collaborators that are unrelated to the instructors of the course, which in turn involves risks and difficulties. Firstly, it is difficult to generate return expectations in these collaborators; hence, their commitment with the course might be affected. Moreover, agenda difficulties, delays or moving costs easily arise. Finally, in order to keep the participation of these external agents in a controlled environment, it is required that they are motivated and committed. In our case, we have taken advantage of the interuniversity collaborative framework (Jaime et al. 2013) to find collaborators (instructors and researchers) with these characteristics. The communication with students has been performed using communication tools such as email or videoconference.

We have introduced several types of stakeholders along the projects. Collaborators have been asked to play some of the following roles, whereas other roles have been played by peer students:

- *Clients* They are represented by an interlocutor (a role played by the organizing instructors). The developing team must generate in these interlocutors expectations that can be assumed in fixed periods and costs. Additionally, they should try to satisfy their requirements, wishes and opinions. This role appears explicitly for the first time in Project P3, and it is kept in Project P4.
- *Organizational direction* Projects are developed within the limits imposed by the organization. The organization representative (an executive played by the organizing instructors) is introduced in Project P4.
- *Final users of the project* The profile of these people is present since Project P3 and specially in Project P4. The client is in charge of transmitting such a profile to the students that develop the project. This role is latent in the project and is not played by anyone.
- *Contents and services providers* In order to integrate contents and services in the projects, it will be necessary to acquire them fulfilling the requirements associated with their licenses. The kind of the developed products involves the necessity of incorporate

third party contents. For instance, in Project P3 it is interesting to integrate contents developed in P2 by other students. In this way, we incorporate the acquisition management with enough realism and without excessive complexity. The acquisition management is introduced optionally in Project P2, but it is compulsory in Projects P3 and P4.

Quality management includes the quality of the product, the management and organizational aspects. In Project P1, students tackled basic questions related to how the quality of the learning process is managed and accredited. In the rest of the projects, students work the definition, evaluation and improvement in both the quality of the product and the management of the project.

An activity related to the quality management, wherein all the students are involved individually, is the assessment of the quality of a set of 18 products (six from Project P2, six from Project P3 and six from Project P4). For each project, the instructors from each university pick a subset of three products from their university. The products are selected regarding their quality and to be a sample of good and bad products—this facilitates the comparison. Before the assessment, the students are not aware whether their products will be selected. The assessments are carried out after the deadline, but close to that date; and all the products are valuated in the same session. Therefore, products are assessed and compared at the same time. The assessments given by the students do not influence the final grade of either the valuated team or the assessing student (provided that the assessment is performed and is done properly).

The chosen products are assessed using a rubric that contains several questions related to particular aspects of the work. An overall valuation is also included. For each question, a five-point Likert scale ranging from 5 (Very good) to 1 (Very bad) is employed. For instance, if a video of Project P2 is assessed, we ask four questions about the plot, the quality of the sound, the quality of the image and an overall valuation of the video. Additionally, students are asked to include comments about the positive and negative aspects of each product. Finally, students must introduce an identification code; hence, assessments are not anonymous for the instructor (we consider that students should be able to justify their valuations). The PA is performed using Google Forms available online. To that aim, instructors create a form for each set of valuated products. For each product, this form includes a page that contains the link to the Web resource and the rubric to assess—these forms can be easily developed, customized and published. In some cases, the synthesis of the gathered valuations has been made available to students almost automatically after the valuation process—Google Forms collect the assessments

in a spreadsheet and allow the user to show the grouped (and anonymized) results for each valuated product. The aim is to show the student how his work is perceived from the outside.

In addition to technical competences, contextual and behavioral competences should also be considered in project management (ICB-IPMA 2006). These competences include ethic, legality and knowledge of professional norms and practices. Related to these topics, the PMI code of ethics and professional conduct (PMI 2013) has been introduced in Project P1 as reflection framework and as an example of the normalization and good practices processes. In Project P2, legal aspects related to intellectual property and usage of licenses are introduced. Aspects about the Web accessibility and data privacy are considered in Project P3. Finally, the contractual framework is introduced by means of a normalized model. Additionally, students are also asked to study the national legislation of personal data and information technology services.

# Method

## Research Design

In order to test the aforementioned hypothesis, in this work we include a quasi-experimental study that was carried during the academic years 2012, 2013 and 2014. The context of this study is two courses related to the introduction to computing project management in the computing science degree of two face-to-face and distant universities (UPV/EHU and UR, from now on called U1 and U2 respectively). As previously mentioned, both courses share the general goal, most of the competences to be developed, the number of credits, the level (third level) and the semester (second semester). Using the approach described in the previous section, students from each university work in teams creating a family of four products that are available online. In the first academic year (2012), neither self-assessment nor PA was included. The group of students of this year is named "without peer assessment." In the other two academic years, three classes of students exist: two in University U1 and one in University U2. One class from University U1 and the class from University U2 form the "assessors and assessees" group. The projects developed within this group are the ones that are selected for peer assessment. Finally, the other class from University U1 is the "assessors" group—the members of this group know that their projects are not selected to be peer assessed. Both students groups are fixed and defined from the beginning of the course. In all the cases, we will use the grade (between 0 and 10) given by the instructors as

method to measure the quality of a project. Such a grade is adjusted to the increasing requirements that can be demanded in each round of projects. Moreover, the grade is not influenced by peer or self assessment.

## Sample

The total number of students that have participated in this experience is 154; 125 of them are males (81.2 %). The students are divided into groups as follows: "without peer assessment" group, 25 students (seven from University U1 and 18 from University U2); "assessors and assessees" group, 97 students (48 from University U1 and 49 from University U2); and "assessors" group, 32 students from University U1.

## Results and Discussion

Table 3 shows the grades (mean and standard deviation) of Projects P1–P4 obtained by students and split depending on the kind of assessment: without peer assessment, students acting only as assessors or students acting as assessors and assessees. It has been checked that the four variables corresponding to those grades follow a normal distribution in the different groups of students. We apply repeated ANOVA measures to test differences among the four projects and then a dependent $t$ test for paired samples between consecutive projects.

The three groups obtain significant differences (rANOVA) among the four projects. Moreover, it is noticeable that the grades are increased progressively in all the groups (except in a case where they slightly decrease). Additionally, the difference between Projects P1 and P2 is not significative in any group. However, while the improvement in the "without peer assessment" group is not significative between Projects P2 and P3 and between Projects P3 and P4, it is actually significative in the other two groups. It is worth reminding that PA is introduced after finishing Project P2; hence, until then, the same method is applied to the three groups (a combination of PBL and SL). Moreover, the improvement in the "assessor" group and "assessors and assessees" group is bigger

between Projects P3 and P4 than between Projects P2 and P3. Finally, there are not differences in the behavior of the group that only evaluates projects developed by other students and the group that acts as assessors and assessees.

We can observe the existence of two interrelated factors. First, the fact that there exists a method based on spiral improves the quality of projects. Additionally, the improvement is more noticeable after the introduction of peer assessment (from Project P2). This result confirms our first hypothesis: The PBL method in spiral means an improvement in the students throughout the projects that compose the spiral. Additionally, such an improvement is increased when the students participate in a peer review process.

Methods based on spiral teaching have been documented in the literature, and in such works, it has been observed an improvement in the grades regarding traditional teaching. For instance, the authors of (Jing et al. 2011) experimented with a method of spiral teaching in an embedded system course, and they noticed an enhancement in comprehension of the learning contents over the conventional method. The authors of that work explain that such an improvement occurs because knowledge must be revisited in short periods of time. They also perceived that the motivation of the students was high and kept through the course, probably, because students were able to complete an embedded system on their own. In another similar experience in computer programming courses (Vega et al. 2013), the average grade of students increased and it was also observed high levels of motivation. Methods based on spiral have been also proposed in engineering education, where the spiral is carried out throughout several courses. A study with chemical engineering students observed an improvement in the students' technical proficiency (DiBiasio et al. 2001). Another study with courses related to hardware description languages identified that the understanding of the concepts progressively improves through the course sequence (Vemuru et al. 2013).

The improvement derived from acting as assessor in PA is documented in several studies, where it is observed that giving feedback, or peer observation, has a significative impact on learners, while receiving feedback is not so influential. In an experience with high-school students (Lu

**Table 3** Mean (standard deviation) of the grades given by the instructor to Projects P1–P4 and split depending on the kind of assessment: without peer assessment group, assessor group and assessors and assessees group

| Students' group | N | P1 | P2 | P3 | P4 | rANOVA | t test |
|---|---|---|---|---|---|---|---|
| Without peer assessment | 25 | 5.56 (1.26) | 5.83 (1.32) | 6.32 (0.87) | 6.74 (1.14) | $F = 9.049$*** | P1 $\simeq$ P2 $\leq$ P3 $\simeq$ P4 |
| Assessors | 32 | 6.36 (1.06) | 6.32 (0.85) | 6.70 (0.66) | 7.98 (0.80) | $F = 39.521$*** | P1 $\simeq$ P2 $\ll$ P3 $\ll$ P4 |
| Assessors and assessees | 97 | 6.65 (1.41) | 6.82 (1.05) | 7.18 (1.07) | 7.94 (1.23) | $F = 43.710$*** | P1 $\simeq$ P2 $\ll$ P3 $\ll$ P4 |

The following notation is used: $\leq$: $p < 0.1$; $<$: $p < 0.05$; $\ll$: $p < 0.01$; *** or $\lll$: $p < 0.001$; $\simeq$: no significant differences

and Law [2012]), it was noticed that the more problems assessors identified, and the more suggestions they made, the better they performed in their own projects. In a study in the context of learning how to write English (Rouhi and Azizian [2013]), the authors suggested that this benefit comes from the fact that thinking more deeply during making PA might trigger to reflect on students own work. The same effect has also been identified in an introductory physics university course (Cho and Cho [2011]; Cho and MacArthur [2011]) and in a study performed in several disciplines (Chen et al. [2009]).

In all the studies that we have found, they compare the quality of a second version of a work with respect to the first version (Rouhi and Azizian [2013]; Cho and Cho [2011]; Lu and Law [2012]; Chen et al. [2009]) or a first work regarding a second similar work on a different topic (Cho and MacArthur [2011]) improved after getting PA. Up to the best of our knowledge, the effect of PA in learning through a sequence of works in a course has not been documented. In our case, it is observed that, when using PA, the quality of the new projects is increased every time in a more noticeable way. This effect is produced not only if students act as assessors and assessees, but also if students act only as assessors.

In Tables [4] and [5], the qualifications (means and standard derivations) of the projects have been split into the students that get a final grade (awarded by the instructor) higher or equal than 7 (over 10) and those who got a grade lower than 7.

In all the groups analyzed in Tables [4] and [5], it is observed that the difference between Projects P1 and P2 is not significative. It is worth remembering that PA was only introduced after Project P2. In the "without peer assessment" group, it can be observed a cycle with significant improvement in both the "best-grades" and the "worst-grades" groups. In this case, students of the "best-grades" group take an additional cycle to show a significant improvement, but it is more pronounced. This shows that the cycle of spiral projects, without PA, produces that students improve in some cycle, but, as we observed, in a different way depending on the kind of student. In all the cases where students participate as assessors (either with the chance of receiving assessment or not), significant differences are noted in the last cycle (from Project P3 to Project P4). However, the enhancement detected in the second cycle (from Project P2 to Project P3) is uneven; there exist significant differences in the case of "best-grade" students that might receive assessment, but there are no differences in the "worst-grade" students of the same group. The students that only provide assessment are kept in an intermediate situation.

In summary, when groups are split depending on the final grade, improvements are still noticed in all the subgroups, and such improvements are more marked in the students of the subgroups that assess products. Additionally, the students from the "assessors and assessees" group that also belong to the "best-grade" group take advantage of PA from the first cycle, whereas, the improvement in the

**Table 4** Mean (standard deviation) of the instructor's grades given to the projects (split according to the assessment method) of the student who got a final grade higher or equal than 7

| Students' group | N | P1 | P2 | P3 | P4 | rANOVA | t test |
|---|---|---|---|---|---|---|---|
| Without peer assessment | 11 | 6.31 (0.88) | 6.66 (0.80) | 6.53 (0.83) | 7.49 (0.98) | $F = 4.738^{**}$ | P1 $\simeq$ P2 $\simeq$ P3 $\ll$ P4 |
| Assessors | 15 | 6.57 (1.38) | 6.59 (0.92) | 6.98 (0.60) | 8.41 (0.71) | $F = 18.604^{***}$ | P1 $\simeq$ P2 $\leq$ P3 $\lll$ P4 |
| Assessors and assessees | 63 | 7.12 (1.29) | 7.20 (0.92) | 7.60 (0.97) | 8.50 (0.95) | $F = 40.542^{***}$ | P1 $\simeq$ P2 $\ll$ P3 $\lll$ P4 |

$\leq$: $p < 0.1$; $<$: $p < 0.05$; $^{**}$ or $\ll$: $p < 0.01$; $^{***}$ or $\lll$: $p < 0.001$; $\simeq$: no significant differences

**Table 5** Mean (standard deviation) of the instructor's grades given to the projects (split according to the assessment method) of the student who got a final grade lower than 7

| Students' group | N | P1 | P2 | P3 | P4 | rANOVA | t test |
|---|---|---|---|---|---|---|---|
| Without peer assessment | 14 | 4.96 (1.21) | 5.17 (1.29) | 6.15 (0.90) | 6.15 (0.90) | $F = 6.869^{**}$ | P1 $\simeq$ P2 $<$ P3 $\simeq$ P4 |
| Assessors | 17 | 6.20 (0.67) | 6.07 (0.73) | 6.45 (0.63) | 7.60 (0.69) | $F = 20.738^{***}$ | P1 $\simeq$ P2 $\leq$ P3 $\lll$ P4 |
| Assessors and assessees | 34 | 5.76 (1.20) | 6.07 (0.88) | 6.36 (0.72) | 6.86 (0.96) | $F = 7.852^{***}$ | P1 $\simeq$ P2 $\simeq$ P3 $\ll$ P4 |

$\leq$: $p < 0.1$; $<$: $p < 0.05$; $^{**}$ or $\ll$: $p < 0.01$; $^{***}$ or $\lll$: $p < 0.001$; $\simeq$: no significant differences

students from the "worst-grade" group is delayed until the second cycle of PA. These results confirm our second hypothesis: the combination of the three teaching methods (PBL, SL and PA) acts differently on high- and low-performance students.

We have not found studies about PA that compare the results of several cycles according to the performance of the students. The study carried out by (Lin et al. 2001) proposed a single iteration of enhancement on a project of operating systems. The students received PA of the first version of the project and tried to improve it in the second version. Their results show that the students with high executive thinking styles (i.e., students that tend to follow regulations and solve problems by designated rules) significantly improved, whereas the students with low executive thinking styles did not improve. This result is similar to what happens in our group of assessors and assessees where, in the first cycle with PA (from Project P2 to Project P3), only the projects of the students with higher grades are improved.

## Conclusions

In this work, we have proposed the combination of three well-known teaching methods: PBL, SL and PA. This bundle of methods has been set on an introduction to project management course in two computer science degrees during two academic years. In a previous year, the proposal was carried out without PA. This allows us to perform a quasi-experimental study with two results. The former indicates that the combination of PBL and SL means an improvement in the successive projects that are created. Moreover, the integration of PA makes such an improvement more significant. The latter result shows that the combination of methods produces different results depending on the quality of the students: the students with higher grades and that act both as assessors as assessees get a more pronounced improvement throughout the cycles of the spiral.

## References

Alba-Elias F, Gonzalez-Marcos A, Ordieres-Mere J (2014) An active project management framework for professional skills development. Int J Eng Educ 30(5):1242–1253

Boehm BW (1988) A spiral model of software development and enhancement. Computer 21(5):61–72

Boubouka M, Papanikolaou KA (2013) Alternative assessment methods in technology enhanced project-based learning. Int J Learn Technol 8(3):263–296

Broman D, Sandahl K, Baker MA (2012) The company approach to software engineering project courses. IEEE Trans Educ 55(4):445–452

Bruner JS (1960) The process of education. Harvard University Press, Harvard

Cameron AF, Trudel MC, Titah R, Léger PM (2012) The live teaching case: a new IS method and its application. J Inf Technol Educ Res 11(1):27–42

Chandrasekaran S, Stojcevski A, Littlefair G, Joordens M (2012) Learning through projects in engineering education. In: SEFI 2012: engineering education 2020: meet the future: proceedings of the 40th SEFI annual conference 2012. European society for engineering education (SEFI)

Chang SH, Wu TC, Kuo YK, You LC (2012) Project-based learning with an online peer assessment system in a photonics instruction for enhancing LED design skills. Turk Online J Educ Technol-TOJET 11(4):236–246

Chen NS, Wei CW, Wu KT, Uden L (2009) Effects of high level prompts and peer assessment on online learners' reflection levels. Comput Educ 52(2):283–291

Cho YH, Cho K (2011) Peer reviewers learn from giving comments. Instr Sci 39(5):629–643

Cho K, MacArthur C (2011) Learning by reviewing. J Educ Psychol 103(1):73

Chua KJ, Yang WM, Leo HL (2014) Enhanced and conventional project-based learning in an engineering design module. Int J Technol Des Educ 24(4):437–458

Cobo-Benita JR, Ordieres-Meré J, M Ortiz-Marcos I, Pacios-Álvarez A (2010) Learning by doing in project management: acquiring skills through a collaborative model. In: Education engineering (EDUCON), 2010 IEEE. IEEE, pp 701–708

Davidovitch L, Parush A, Shtub A (2006) Simulation-based learning in engineering education: performance and transfer in learning project management. J Eng Educ 95(4):289–299

Davidovitch L, Parush A, Shtub A (2009) The impact of functional fidelity in simulator-based learning of project management. Int J Eng Educ 25(2):333

DiBiasio D, Comparini L, Dixon AG, Clark WM (2001) A project-based spiral curriculum for introductory courses in ChE: part 3. Evaluation. Chem Eng Educ 35(2):140–147

Domínguez C, Jaime A (2010) Database design learning: a project-based approach organized through a course management system. Comput Educ 55(3):1312–1320

Fowler M, Highsmith J (2001) The agile manifesto. Softw Dev 9(8):28–35

Frank M, Lavy I, Elata D (2003) Implementing the project-based learning approach in an academic engineering course. Int J Technol Des Educ 13(3):273–288

Geist DB, Myers ME (2007) Pedagogy and project management: should you practice what you preach? J Comput Sci Coll 23(2):202–208

Gibbs G (1999) Using assessment strategically to change the way students learn. In: Brown S, Glasner A (eds) Assessment matters in higher education: choosing and using diverse approaches. S.R.H.E and Open University Press, Buckingham

Guerrero D, Vegas S, Quevedo V, Palma M. (2013) Improving generic skills among engineering students through project-based learning in a project management course. In: ASEE (ed) Proceedings from the 120th ASEE annual conference and exposition

Huang L, Dai L, Guo B, Lei G (2008) Project-driven teaching model for software project management course. In: 2008 International conference on computer science and software engineering, vol 5. IEEE, pp 503–506

ICB-IPMA (2006) ICB-IPMA competence baseline. International Project Management Association, Nijkerk, The Netherlands

Ivanovic M, Putnik Z, Budimac Z, Bothe K (2012, April) Teaching "Software Project Management" course-seven years experience.

In: Global engineering education conference (EDUCON), 2012 IEEE. IEEE, pp 1–7

Jaime A, Domínguez C, Sánchez A, Blanco JM (2013) Interuniversity telecollaboration to improve academic results and identify preferred communication tools. Comput Educ 64:63–69

Jewels T, Albon R (2009) Developing an IT project management course to meet changing industry needs. In: 15th Americas conference on information systems (AMCIS) 2009. San Francisco, USA. Jan 2009

Jing L, Cheng Z, Wang J, Zhou Y (2011) A spiral step-by-step educational method for cultivating competent embedded system engineers to meet industry demands. IEEE Trans Educ 54(3):356–365

Lin SS, Liu EZF, Yuan SM (2001) Web-based peer assessment: feedback for students with various thinking-styles. J Comput Assist Learn 17(4):420–432

Lohani VK, Wolfe ML, Wildman T, Mallikarjunan K, Connor J (2011) Reformulating general engineering and biological systems engineering programs at Virginia Tech. Adv Eng Educ 2(4):1–30

Lu J, Law N (2012) Online peer assessment: effects of cognitive and affective feedback. Instr Sci 40(2):257–275

Machanick P (2005) Peer assessment for action learning of data structures and algorithms. In: Proceedings of the 7th Australasian conference on computing education, vol 42 Australian Computer Society, Inc, pp 73–82

Martín C, Urpí T, Casany MJ, Xavier Burgués X, Quer C, Rodríguez ME, Abelló A (2013) Improving learning in a database course using collaborative learning techniques. Int J Eng Educ 29(4):1–12

Nembhard D, Yip K, Shtub A (2009) Comparing competitive and cooperative strategies for learning project management. J Eng Educ 98(2):181–192

Palmer S, Hall W (2011) An evaluation of a project-based learning initiative in engineering education. Eur J Eng Educ 36(4): 357–365

PMI (2013) A guide to the project management body of knowledge (PMBOK® Guide), 5th edn. Project Management Institute, PA

Prince MJ, Felder RM (2006) Inductive teaching and learning methods: definitions, comparisons, and research bases. J Eng Educ 95(2):123–138

Ramazani J, Jergeas G (2015) Project managers and the journey from good to great: the benefits of investment in project management training and education. Int J Proj Manag 33(1):41–52

Rouhi A, Azizian E (2013) Peer review: is giving corrective feedback better than receiving it in L2 writing? Proc Soc Behav Sci 93:1349–1354

Søndergaard H, Mulder RA (2012) Collaborative learning through formative peer review: pedagogy, programs and potential. Comput Sci Educ 22(4):343–367

Strijbos JW, Sluijsmans D (2010) Unravelling peer assessment: methodological, functional, and conceptual developments. Learn Instr 20:265–269

Thomas JW (2000) A review of research on project-based learning. The Autodesk Foundation, San Rafael

Topping KJ (2010) Methodological quandaries in studying process and outcomes in peer assessment. Learn Instr 20(4):339–343

Tynjälä P, Pirhonen M, Vartiainen T, Helle L (2009) Educating IT project managers through project-based learning: a working-life perspective. Commun Assoc Inf Syst 24:1–21, Article 16. http://aisel.aisnet.org/cais/vol24/iss1/16

Vega C, Jiménez C, Villalobos J (2013) A scalable and incremental project-based learning approach for CS1/CS2 courses. Educ Inf Technol 18(2):309–329

Vemuru S, Khorbotly S, and Hassan F (2013) A spiral learning approach to hardware description languages. In: 2013 IEEE international symposium on circuits and systems (ISCAS). IEEE, pp 2759–2762. doi:10.1109/ISCAS.2013.6572450