# Spiral and project based learning with peer-assessment in a computer engineering project management course

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## Abstract

Background

Different learning methods such as project based learning, spiral learning and peer-assessment have been implemented in engineering disciplines with different outcomes.

Purpose/Hypothesis

This paper presents a proposal for a project management course in the context of a Computer Engineering 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.

Design/Method

The proposal has already been implemented and validated for the last three 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 two 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.

Results
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 on poor-performance students is delayed.

Conclusions
The integration of spiral project based learning with peer-assessment enhances the benefits of both methods.

**Keys**: Project based learning, spiral learning, peer assessment, project management.

## 1. Introduction

Engineering degrees usually include a course to develop the competences related to project management (PMI, 2013; ICB-IPMA, 2006) --- the discipline of organising 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 Engineering 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).

**PBL** is a widely-spread pedagogical method where the course is designed around one or more projects. PBL is characterised 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 et al., 2010; Prince & Felder, 2006), 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 & 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 & 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, 1998) 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, M. & 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 (Sondergaard & 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, and concrete management goals (of contextual type) and behavioural 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 10 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-engineering project management course that has been successfully implemented during several academic courses.
- Analyze the influence of combining the three methods 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.

We want to contrast the following hypotheses:

1. The PBL method in spiral means an improvement on 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.

## 2. Related work

A review of pedagogical trends for project management in universities and colleges was provided in (Geist & Myers, 2007). The majority of educators agrees 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 & 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 modelling, 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 & Hall., 2011; Frank et al., 2003). PBL has been incorporated by means of three projects to a design and professional skills course (Palmer & 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-Elias et al., 2014) in the framework of contractual, laboral and organisational 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 organisation, 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 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., 2009; Davidovitch et al., 2006; 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 & 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 partipates, was presented in (Jewels et al., 2009).

The authors of (Boubouka & Papanikalaou, 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 & 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, realising their errors and deficiencies. In this way, staged project work (Sondergaard & 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 (Sondergaard & 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 & Papanikalaou, 2013), jeopardising 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 (Sondergaard & 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 (Machnick, 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.

# 3. Teaching proposal: projects spiral and peer assessment

As we have previously explained, our teaching proposal is structured around 4 projects that are carried out through 13 weeks and which duration, involvement, and complexity is increased progressively. We will call these projects P1, P2, P3, and P4. Projects P1 and P2 last two weeks, Project P3 three weeks, and Project P4 six 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 organised by the instructor.

**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 | Website with 4’ video and license. It also includes 3 P2 videos and interaction form with the visitor | Multilingual wordpress website with license, a 4’ P3 video, several P2 videos, interaction form with the visitor and interesting links. Accordance with WAI-A & 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 & controlling | Monitoring with comparison between estimated and real times | | Monitoring & control with comparison between individual and collective estimated and real times | Monitoring & control with comparison between individual and collective estimated and real times. Monitoring & control of the different plans |
| Lessons learned | Personal list of individual lessons learned | | | Common knowledge base with lessons learned |

Table 1 gathers the characteristics of the products developed in the 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 plurilingual website developed using a widespread content manager (e.g. wordpress) that must be fully functional and be available at least three weeks.

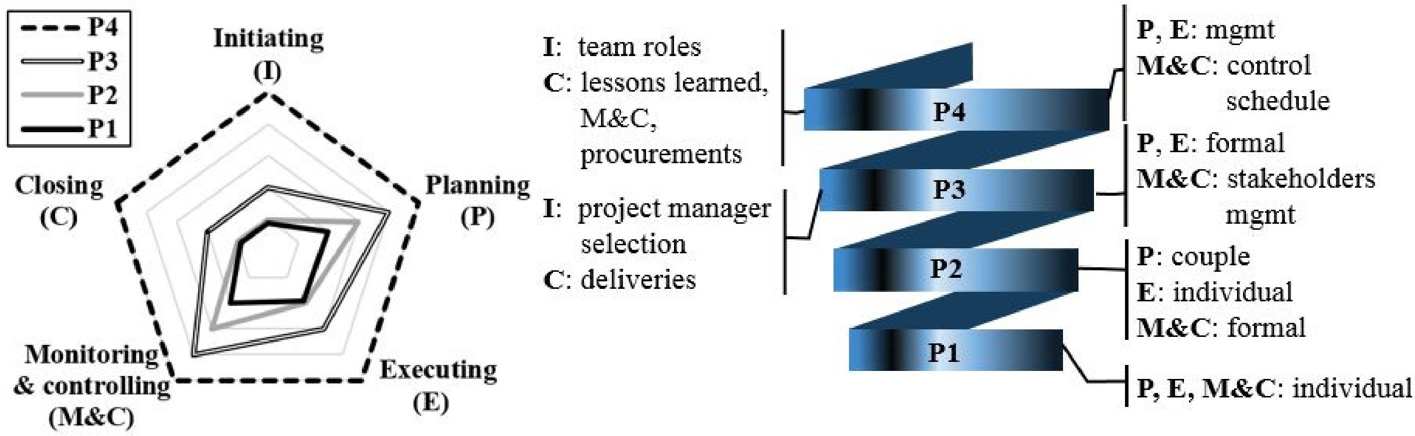


Figure 1: PMBoK management process groups in the different projects.

Table 1 also collects 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 Figure 1, all the projects consist of significant elements of the five phases of the project life cycle: initiating, planning, executing, monitoring and controlling, and closing.

**Table 2 -** PMBoK knowledge areas covered in the different projects.

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


Figure 2: PMBoK knowledge areas covered in the different projects.

Table 2 summarises the treatment given in each project to each one of the 10 knowledge areas of PMBok. Figure 2 represents how the complexity of the tasks associated with each area is increased. 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 organisation 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 engineering 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 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 (Authors, 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 organising instructors). The developing team must generate in these interlocutors expectations that can be assumed in fixed periods and costs. Additionally, the 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.
- *Organisational direction*. Projects are developed within the limits imposed by the organisation. The organisation representative (an executive played by the organising 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 organisational 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 of 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 (6 from Project P2, 6 from Project P3 and 6 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 instance, if a video is assessed, we can ask about the plot, the quality of the sound or the image, before asking the 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, customised 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 anonymised) 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 behavioural competences should also be considered in project management (ICB-IPMA, 2006). These competences include ethic, legality, and knowledge of professional norms and practises. 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 normalisation and good practises 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 normalised model. Additionally, students are also asked to study the national legislation of personal data and information technology services.

# 4. Method

## 4.1. 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 Engineering degree of two face-to-face and distant universities (U1 and U2). 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 were included. The group of students of this year is named “without peer-assessment”. In the other two academic years, three classes of students exists: two in University U1 and one in University U2. One class from University U1 and the class from University U2 form the “assessors & assesses” 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.

## 4.2. 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 (7 from University U1 and 18 from University U2); “assessors & assessess” group, 97 students (48 from University U1 and 49 from University U2); and, “assessors” group, 32 students from University U1.

# 5. Results and discussion

Table 3 includes 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.

**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 & assesses group.

| Students' group | N | P1 | P2 | P3 | P4 | rANOVA | t-tests |
|---|---|---|---|---|---|---|---|
| Without peer-assessment | 25 | 5.56 (1.26) | 5.83 (1.32) | 6.32 (0.87) | 6.74 (1.14) | F=9.049*** | P1≈P2≤P3≈P4 |
| Assessors | 32 | 6.36 (1.06) | 6.32 (0.85) | 6.70 (0.66) | 7.98 (0.80) | F=39.521*** | P1≈P2<<P3<<<P4 |
| Assessors & Assessees | 97 | 6.65 (1.41) | 6.82 (1.05) | 7.18 (1.07) | 7.94 (1.23) | F=43.710*** | P1≈P2<<P3<<<P4 |

**The following notation is used:** ≤: p<0.1; <: p<0.05; <<: p<0.01; *** or <<<: p<0.001; ≈:no significant differences

The three groups obtain significant differences (rANOVA) among the 4 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 & assesses" group is bigger between Projects P3 and P4 than between Projects P2 and P3. Finally, there is not differences in the behaviour of the group that only evaluate projects developed by other students and the group that acts as assessors & assesses.

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 on 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 of 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 & 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 & Azizan, 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 & Cho, 2011; Cho & MacArhur, 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 & Azizan, 2013; Cho & Cho, 2011; Lu & Law, 2012; Chen et al., 2009) or a first work regarding a second similar work on a different topic (Cho & MacArhur, 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.

**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≈P2≈P3<<P4 |
| Assessors | 15 | 6.57 (1.38) | 6.59 (0.92) | 6.98 (0.60) | 8.41 (0.71) | F=18.604*** | P1≈P2≤P3<<<P4 |
| Assessors & Assessees | 63 | 7.12 (1.29) | 7.20 (0.92) | 7.60 (0.97) | 8.50 (0.95) | F=40.542*** | P1≈P2<<P3<<<P4 |

≤: p<0.1; <: p<0.05; ** or <<: p<0.01; *** or <<<: p<0.001; ≈: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≈P2<P3≈P4 |
| Assessors | 17 | 6.20 (0.67) | 6.07 (0.73) | 6.45 (0.63) | 7.60 (0.69) | F=20.738*** | P1≈P2≤P3<<<P4 |
| Assessors & Assessees | 34 | 5.76 (1.20) | 6.07 (0.88) | 6.36 (0.72) | 6.86 (0.96) | F=7.852*** | P1≈P2≈P3<<P4 |

≤: p<0.1; <: p<0.05; ** or <<: p<0.01; *** or <<<: p<0.001; ≈:no significant differences

In all the groups analysed 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 not 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 & assesses" group that also belong to the "best-grade" group take advantage of PA from the first cycle; whereas, the improvement of the 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 assesses where, in the first cycle with PA (from Project P2 to Project P3), only the projects of the students with higher grades are improved.

## 6. 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 engineering 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 assesses get a more pronounced improvement throughout the cycles of the spiral.

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