Projects with the industry for the development of competences: a case study in industrial engineering and management

Abstract
This paper presents a learning process based on PBL concepts, where five teams of 5 to 7 students of Industrial Engineering and Management (IEM) from the University of Minho, Portugal, developed semester projects in interaction with companies, supported by 5 courses. The paper aims to describe the operational model of this PBL process, evaluate the results in terms of students’ learning and perception of industry, and, finally, develop improvement proposals for the model. The evaluation of learning outcomes is based on project results’ analysis, questionnaires and a closing workshop with students. The perception of industry is achieved using semi-formal interviews with company representatives. This evaluation points out that students have developed the expected competences and, generally, they are pleased with the outcome of their projects. They referred that there should exist better mechanisms of differentiation of individual classifications within the team. The companies’ viewpoint refers good results, although sometimes the improvement proposals are not sufficiently focused. To overcome this issue some process improvements are proposed.

Keywords: project-based learning, professional competences, interaction with industry.
1. INTRODUCTION
The higher education all over the world is adopting teaching and learning methodologies more student-centered and where the student plays a more active, participatory and collaborative role in the learning process. In Europe this trend was clearly enhanced by the "Bologna Process" which started with the "Sorbonne Declaration" signed in 1998 and was reinforced by the Bologna Declaration, signed in June 1999. This declaration advocates the construction, in a time horizon of ten years, of a cohesive, harmonious, competitive and attractive European Higher Education (1) (2). The Bologna Process implies a new kind of education, focusing on acquiring and developing skills by active involvement of students in the learning process. Furthermore, the Bologna Process promotes a change in higher education to explicitly include the development of both transversal competences and technical competences. According to Veiga Simão (3), emphasis should be given to problem solving, creating an environment conducive to the development of technical and transversal skills. Some of these transversal skills, like the ability to communicate effectively and the ability to work in multidisciplinary teams, are listed by ABET (4). Communication skills, teamwork and project management are also referred by EUR-ACE (5), as part of the skills to be developed during the engineering programs.

Project-based learning is an active learning approach that is aligned to the main trends of today’s engineering education and for many reasons it was selected by a group of teachers from the Department of Production and Systems at the University of Minho to be included in their courses. The PBL approach adopted in the Industrial Engineering and Management (IEM) degree followed the Project Led Engineering Education (PLEE) model proposed by Powell & Weenk (6) and is for many years being implemented in the first and fourth year of the IEM degree (7). This paper is focused only on the PBL editions involving students from first semester of the fourth year taking place in a real industry context. The main believe behind the PBL in industry context is that it improves the learning effectiveness and efficiency both in terms of developing technical and transversal competences. Learning by doing and the link between theory and practice are believed to be better achieved by project work in real industry context. As suggested in some works, practical training increases students’ understanding of theoretical knowledge and motivation to study (8) (9).

This paper describes the Project Based Learning approach that we are carrying out in industry context in the IEM degree. The main objective of this work is the evaluation the effectiveness and efficiency of the learning process in terms of the development of technical and transversal competencies. The evaluation of learning outcomes is based on project results’ analysis, questionnaires and a closing workshop with students, regarding the 2011/2012 PBL edition. Thirty one students were involved in the project, organized in five teams, each team in each separate company. We also present in this paper the perception of the industry about this type of projects by using semi-formal interviews with company representatives.

2. PBL REVIEW
Project Based Learning (PBL) is a learning methodology that’s not new. The origins of a learning approach which put students with an active role on learning process started with John Dewey (10) work. PBL assumes this principle but with a renewed attention. This attention comes from the aware that are some competences, in particular, transversal competences that are not learnt by the students in the traditional teaching methodology, i.e., centred on the teacher. Transversal competences like teamwork, interpersonal development skills, project and time management, problem-solving skills and creativity thinking are some competences that need learning and challenging environment where the students feel they can be involved. In this involvement, the students assume an active role and the learning responsibility and commitment come from them, not from the teacher that assumes a facilitator role. Thus, one characteristic of PBL is the opportunity to provide learning situations where students have an active participation.
The commitment referred implies also having a purpose or meaning, being this other characteristic of project work defended already in 1918 by Kilpatrick (11). Project works were used as mechanism to integrate various courses and/or academic and practical work, mainly when they are used in projects developed in industry (12). Most of engineering students are, in general, motivated to go to industries and apply their competences on practice. Project work in the industry provides a scenario with real situations and problems. So, the inclusion of this kind of projects in curricula programmes create, normally, strong motivation and engagement in learning process, through the link between theory and practice (e.g. technical contents included in the project). This means action learning, assuming that people learn most effectively when working on real-time problems in a work environment that they know it will be their own work environment (13).

There are some well-known project approaches to learning like the ones from Aalborg, Delft (14) and Twente Universities (6) (15) in north of Europe. A growing interest has increased the application of PBL in other engineering schools like the School of Engineering, University of Minho in Portugal (7) (16) and the Faculty of Technology, University of Brasilia in Brazil (17) (18). PBL approach with industry participation reinforces the demands of European policies to stimulate the relation between universities and enterprises (19) (20). This purpose is based on the concern to prepare students to labour market. That’s why PBL methodology can be a valuable opportunity for students to develop competences that are recognized by the employers and society.

3. METHODOLOGY

This paper draws upon a study which intends to describe the operational model of PBL process with interaction with industry, through an integrated analysis that allows the presentation of proposals in order to improve the current model. Considering the context of the study, the research questions are:

- What are the critical dimensions in PBL process in this context?
- What is possible to do to improve the identified dimensions?

The research questions point out characteristics of a descriptive study. This methodological approach is concerned with finding out “what is” in a specific context, situation or phenomena. According to Krathwohl (24) the value of description emerges from the exploration and helps to organize the findings in order to fit them with explanations that can be developed into recommendations. This research process is based on a number of variables employed and the analysis considers the connection between them. In this study, the variables are related to PBL dimensions and the analysis focus is based on perceptions from the participants. It’s a study in a small scale but the conclusions addresses improvement points or recommendations to be considered in other similar contexts.

Descriptive research uses both quantitative and qualitative methods for gathering data, to describe the context, situation or phenomena which is considered in the study and then organizes, tabulates, depicts, and describes the data collection (21). This is the approach of this study. The data collection was based on different methods and expresses the students’ results achieved with the project, as well as their perceptions about the process. Perceptions from industry representatives which participated in the projects were also considered. These data were all collected at the end of the project using four methods:

- Survey: is composed by closed questions aggregated in six dimensions related to the project (1. project and industry cooperation; 2. learning and competences; 3. teamwork; 4. teachers’ and tutors’ role; 5. assessment and evaluation; 6. PBL as a learning methodology) and three open questions where students must identify positive and less
positive aspects in the project, as well as present suggestions to improve the projects. 21 students from a total of 31 answered to questionnaires corresponding to a response rate of 68%.

- Open Discussion: during the final workshop, with the students and teachers staff, two topics were discussed in small groups, namely the project model and assessment. After discussion each group have to share the results in order to involve all participants in the dialogue.
- Documental analysis: based on students’ learning outcomes and contents applied in the projects.
- Semi-formal interviews: feedback from two industry representatives involved in the project, in regard to the process of interaction with the university and students’ results.

The data analysis is based on the information collected from different sources, accomplishing an integrated analysis about the PBL process. Thus, the dimensions defined in the survey were used as categories of analysis and from this process arises important evidences to be discussed.

4. PBL MODEL
The Integrated Master in Industrial Engineering and Management (IEM) of the School of Engineering of the University of Minho (UMINHO) is a 5 year program with 300 European Credit Transfer System (ECTS) (25). Each credit corresponds to 28 hours of integral work of the student. This program has three PBL semester projects, in the first, seventh and eights semesters of the program. With these projects the course aims to have students more motivated and engaged with curricular objectives, developing both technical and transversal competences. Additionally, with the project of the seventh semester here analysed there is also the objective to put students in interaction with industrial companies.

4.1 Curricular Context and Assessment Model
Since 2005/2006, 7 editions of the PBL project in interaction with industrial companies have been carried out, involving almost 220 students and 13 companies from several industrial sectors (textile, footwear, wood, metal-mechanical, car electronics, hospital equipment and measurement systems). As previously mentioned, this project occurs in the seventh semester of IEM and all the courses of that semester are Project Supporting Courses (PSC): (i) Organization of Production Systems II, (ii) Information Systems for Production, (iii) Production Integrated Management, (iv) Ergonomic Study of Workplaces, and, (v) Simulation. A sixth course – Integrated Project I – materializes the PBL project in terms of IEM curricular structure. This paper is focused on the most recent project edition (2011/12) which engaged 5 teams, totalling 31 students, and 5 distinct companies (section 4.3). Besides the usual classes, each PSC teacher is also responsible for 2 contact hours/week (in the ambit of Integrated Project I course) dedicated to the accompanying of the students’ teams, to ensure the development of the adequate technical skills. Each team of students is entitled to a tutor, whose main role is the monitoring of the project progress, involving a weekly meeting (1 hour). In technical terms, the tutor should only contribute for the development of the team’s project management competences (including decision making, conflict management, etc.), even if she/he has specific PSC knowledge. The assessment model is somehow elaborated - the final grade of a specific student in a specific PSC course (course X) is computed from:

- Individual grade obtained in the project (weight x%).
- Individual grade obtained in the continuous assessment of course X (weight 1-x%).

Each PSC defines the weight of the project (x%) in its assessment:
The individual grade in the project is obtained by multiplying the team grade in the project by a
individual correction factor determined by a peer assessment process. Within the team, the
average value of the individual correction factors must be 1. Each team has the responsibility to
define the number of peer assessment sessions conducted during the semester as well as the
correspondent criteria.

4.2 Project Objectives
The project to be undertaken by students is complex, has a unique solution and should be
challenging for both the students and for teachers. Moreover, students must develop the learning
skills related with courses directly involved in the project. The objective of this project of the
first semester of 4th year is to make the analysis and present proposals for improvement of the
production system of a company. With the support of teachers, students should manage the
interaction with an industrial company under the established partnership and present suggestions
for improvements to their production system. To achieve this objective it will be necessary to
analyze the production system considering the following objectives withdrawn from the 2011/12
project guide (26):

- Characterize and classify the production system
- Describe and diagnose the existing production system and evaluate its performance
- Identify production wastes
- Identify the key functions of production planning and control, how they relate to each other
  and the processes / techniques currently used for implementation
- Define possible alternatives of action for improvement and expected results

This analysis will form the basis for proposals for improvements to:

- Selection of models and techniques used for production planning and control
- Specification of new performance measures.
- Change of layouts, material flow and its control
- Changes in organization of jobs and production units
- Design of new organization and management solutions for the production.
- Specification of partial configurations solutions for the information system for production
  planning and control.
- Modifications to the design of workplaces;
- Control parameters of the physical environment of production workstations.
- Selection of the best alternatives.

4.3 Industrial interaction
The 5 teams of students participating in the 2011/2012 PBL edition carried out their project in
completely different company. The process of selection of companies was performed entirely by
students and therefore they end up with 5 different companies, varying in terms of products type,
size and organizational culture. The characteristics of each company were:
• A company dedicated to car multimedia products. Large company integrated in a large multinational group, pursuing lean culture and with high degree of lean tools implemented. This company includes automatic and manual insertion of electronic components as well as manual assembly of car multimedia products in many assembly cells and lines.

• A company in the garment industry sector. Small company with around 50 employees, without any lean culture or lean tools implemented. This company is organized around two main swing lines.

• A metalworking company dedicated to the production of components to water taps. Small company with around 40 employees, without any lean culture. The production is organized in a traditional job shop layout.

• A metalworking company dedicated to the production of saws and files. It is a small plant with around 70 employees, integrated in a large multinational group, pursuing lean culture and with an interesting degree of lean tools implemented.

• A large manufacturer of steel cylinders for low-pressure gases. With around 300 employees in the plant where the project took place. They are just starting the implementation of lean tools.

The degree of interaction between the students and the company varied but in most cases the companies’ representatives followed the projects very closely and with high interest in the results.

5. RESULTS
The students’ perception about the project focused on six dimensions of analysis was collected: project; competences and learning; Project-Based Learning methodology; assessment model; teamwork; teachers role. The results were compiled for all students and this section presents the results graphs and analysis.

5.1 Project
Regarding the perception about the project (Figure 1), in general students have a positive view, mostly averaging between 3 and 4 (in a scale from 1 to 5). The main disagreement is in item 6 in which most students find that the company should not be selected by themselves. From the 21 responses to the questionnaire only two students assigned a positive weight exceeding 3. Item 5 is the one where there is greater dispersion of responses, with standard deviation of 1.5. There is therefore an indication that this item is less consensual, with students who feel that should be the same company for all groups and others who do not give so much importance to this aspect.

![Figure 1: Project general perceptions](image-url)
In the open questions of the questionnaire this dimension as two items that has been strengthened: interaction with industry; learning is in accordance with the professional profile of IEM area. A sample of two answers to the question what you considered more positive:

*Interaction with people outside the university, companies and workers, summarizing what awaits us in the world of work, because it is a small sample of the problems and difficulties which we may face. Thus we get an idea of what awaits us and we are become more able to solve problems by ourselves. Student 9*

*The teamwork and interaction with the industrial environment and the company's employees. Student 12*

A less positive aspect of this interaction is the difference between companies and the need to be selected by the students.

*The beginning was no so good and the working groups got very different companies that do not allow a fair evaluation of all groups. The weight that the project has in certain courses with some areas being assessed, in some cases, three times (project, tasks, and testing). Student 12*

The representatives of the two companies that were interviewed showed some similarities and some differences. Both companies have shown understanding of the project model related with the integration of various courses. Therefore consider that the project cannot be too focused on a specific issue of the company although the company B would prefer this second approach. The company A said that a variety of methodological and conceptual approaches from the various courses has been interesting for the company. The second company (B) reported a not so deep knowledge about the outcome of the students, but still feels that the students managed a project of interest to the company. The first company (A) considered that the students presented an innovative proposal, which surprised them and deserves to be studied. To this company the result obtained by the students was a good result as can be seen by the following excerpts:

- "Considering the time of the project the students got to where I did not expect."
- "They understood the operation and found alternatives that deserve to be studied."
- "Positive project with a lot of interest." Company A

Regarding the question, would repeat participation in the project? Both companies showed answered positively only conditioned by the specific time in its realization.

### 5.2 Competences and Learning

For all dimensions analysed, those who had a more positive result considering the perceptions of the students were learning and skills development (Figure 2) and PBL methodology (Figure 3). These two dimensions have the highest values regarding the average of results and lower values regarding standard deviations. The development of the professional profile is the item with the most positive result of all inquiry, along with another item related to teamwork. Regarding learning aspects, the students considered the development of competences is in accordance with the professional profile and develop the capacity to face challenges related to project management, communication, application of theory to real situations and strengthen the understanding of the contents, becoming more autonomous. The competence considered less developed is to give feedback and develop critical thinking. Still, it has a positive weight, although with the higher standard deviation of this dimension (1.1) indicating a considerable differences among students.
5.3 Project-Based Learning Methodology

The methodology implemented in this semester of the program has a very positive perception from the enrolled students. It may be noted that students consider that the methodology requires teamwork by teachers and has a positive impact on the relationship between students and teachers. The methodology also contributes to the understanding of the profession and the fact that the project is open is considered a challenge for students. Items with less positive perception are the "importance of the previous experience of the 1st year" and the “organization of the project”, both with valuation of 3.2. In both items there is a relevant range from the viewpoint of the responses.

Analysing the open questions on this dimension, it was possible to identify several references to less positive issues relating to the organization, namely:

"Some lack of organization on the part of teachers; absence of posting technical details for preparing the report." Student 18

5.4 Assessment Model

The project assessment is always a critical dimension from the point of view of students. However, students are generally satisfied with the results of the project, the evaluation model (only 4 students with a negative perception valued with 2), with the clarity of feedback from teachers and feel that they have read and understood the assessment criteria.

The most critical aspect is that of the peer assessment performed within each team of students to distinguish the individual grades. This item has an average rating of 3.0 and a standard deviation of 1.5 which shows a great variety in the perception of the students. There is evidence that students consider that the result of peer assessment does not reflect correctly the different
performance within the team. It should however be noted that students believe that ratings should be different according to student performance. Some of the items don’t reveal a strict dissatisfaction but rather a position regarding the assessment model, including: weight of the project should be less than that of courses (with high standard deviation of 1.4); as planned, the classification of the project should be individualized; as implemented, they believe a written test about the project should not exist; and the number of milestones should be reduced.

![Figure 4: Assessment Model](image)

### 5.5 Teamwork

PBL is an approach centred on teamwork that most students prefer and consider that helps to increase motivation for learning. The two most important skills for teamwork are the active role and interpersonal relationships, followed by the sharing of tasks and a positive resolution of conflicts within the group. It can be observed by Figure 5 that the item students consider less important is the implementation of formal meetings for internal organization of the teams.

![Figure 5: Teamwork](image)

Companies were asked about the behaviour and commitment of students and both said they behaved correctly with professional ethics. The company A said that students prepared carefully the visits and ran all the relevant departments to collect information and manage to correctly understand the company. Comments like this have been recurring in contacts made with other companies throughout the semester.
5.6 Teachers Roles
In this PBL model teachers have two different types of role, the teacher role related to giving technical support on the contents and development of associated competences; and the teacher role (tutor) for supporting one or two teams in developing the project and developing of transversal competences.

![Image: Teacher and Tutor Roles](image)

Analysing open questions it emerged some comments about teachers’ role. In particular considering that teachers have little time available or are not sufficiently engaged.

"Little willingness of teachers to answer to questions at certain times; low tutor support." Student 18

"They (teachers) criticized some groups for not being integrating contents in the project in a visible way. I think there this requires more support from the tutor and the whole team because sometimes integrating some things was not easy, as regarding EEPT (course on ergonomics) and other things that were required and that in some companies did not make sense." Student 8

6. Final Remarks
In this work we sought to identify the critical dimensions and their possible contributions to the improvement of the current model, according to the perceptions of students and companies involved in the edition 2011/2012.

The analysis of the results leads us to reflect on the process of project-based learning within the principles of the PBL. Although most results with the students’ perception about the dimensions have been evaluated positively, we highlight some pertinent observations, according to the views of students, which should be carefully examined, including: the selection of the companies for project development, project organization, feedback and development of critical thinking, the peer assessment model, final weight of the project regarded the courses, the final individual grades according to the performance of students in the project, number of milestones, teamwork formal organization with meetings and existence of formal roles in the group and finally, teacher role as a tutor. All these considerations should support the coordination team and teaching staff of the program during the planning of future editions, in order to improve the process.

Considering the comments of the companies, the students’ and teachers’ perceptions on the results of the project and also the interaction with companies throughout the semester and in the final, the teaching staff proposed an alternative organization for the next year project.

The proposal organizes the project into two very distinct phases: analysis and diagnosis phase; improvement phase. This change would explore the contents and skills expected of all courses during the analysis and diagnosis phase and in second phase the project would focus on developing specific solutions for the enterprise.

The first phase would have a development similar to what currently exists and the monitoring of all teachers in order that their marks and influence will have an equally impact on the project.

In the second phase there would be a selection of one or more proposals for improvement in a concerted decision among all stakeholders: students, teachers and companies. So that it is possible to improve the relevance of the project for the company, for students and also for
teachers. The evaluation of this phase would be conditioned only by the courses involved in the selected improvement proposals. We conducted a brief survey to measure receptivity to this new model and both students and companies believe that this will be an interesting alternative to the project organization.

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References