

Development and Assessment of Engineering Project Management Competences in the context of Project-Based Learning (PBL)

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Abstract

The International Association of Project Management (IPMA) has defined the Individual Competency Baseline (ICB) as a three-dimensional competency structure that the project management professional must develop: competences focused on practice, people, and perspectives. The ICB presents as an example the following approaches to developing competences: self-development, peer development, teaching and training, mentoring, and through simulation and games. Some of these examples are related to active learning, which enables greater autonomy of the student, stimulation of creativity, encouragement of communication and teamwork with frequent feedback from the teacher. In the Masters of Engineering Project Management of the University of Minho, Portugal, there are two courses focused on the development and assessment of competences focused on people, designed to provide moments of active learning. This paper aims to analyse how these courses have contributed to the development and assessment of people-focused competences through Project-Based Learning (PBL) and portfolios. This study is based on a documentary analysis of 70 portfolios of one academic year of the two courses, and a focus group of 10 students, in order to understand their perception about the impact of different teaching-learning moments. The results showed that the development of competences has been more enriching for the students, when compared to learning more centred in the teacher than in the student. The specificity to develop and create the activities (development of an individual portfolio) was proven in the study, as well as projects with real contexts are fundamental for the development of personal competences, being the most outstanding teamwork, communication, conflict management and interpersonal relationship. Finally, the results show that the development and assessment of competences with teaching strategies using active learning instigates the student to discuss and make practical the presented content.

Keywords: Engineering Education, Competences Development, Competences Assessment, Project-Based Learning (PBL).

1 Introduction

In the context of Project Management, the International Project Management Association (IPMA) presents, in the Individual Competences Baseline (ICB), a competency structure classified in three dimensions that the project management professionals should develop (IPMA, 2015): competences focused on practice, people and perspectives. Thus, for the practice of Engineering Project Management, using the ICB as a basis for identifying the necessary competences, it will also be necessary to deepen the understanding of the concept of competence and find ways to support the development and assessment of these competences. Mesquita, Lima, Flores, Marinho-Araujo, and Rabelo (2015) define "competence" as the process of mobilizing personal resources, such as knowledge, skills, previous experiences, values and beliefs in specific contexts to solve problems. Competence always refers to people (Le Boterf & Garrido, 2005) and relies on how to mobilize resources in a situation or a problem. For this reason, it cannot be reduced to a status or knowledge to be acquired (Le Boterf & Garrido, 2005), but must be represented in a context where competences are materialized. For Lima, Carvalho, Flores, and van Hattum-Janssen (2007) the development of competences must be stimulated and experienced in real contexts in the academic environment. Students acquire a more central role, since the active involvement of the student in the formative assessment is increasingly encouraged.

In addressing the challenges of training new engineers, Project Based Learning (PBL) is an alternative that shows fertility not only to meet the specific technical training of these professionals, but also to promote the learning of people competences, necessary in the work market (Mesquita, Lima, & Flores, 2013). The University of Aalborg in Denmark, with more than 40 years of experience in project-based learning, identified a number

of shortcomings in traditional education (Hansen & Luxhøj, 1995), including the inability to work with others and discuss, the inability to solve creative problems and solve complex problems that require integration of social, economic, legal and technical factors. The goals of project-based learning are to reduce student attrition rate, increase self-confidence, communication competences and creativity, emphasize integrated problem solving, and improve faculty leadership competences to direct project teams to solve interdisciplinary problems (Lima, Carvalho, Assunção Flores, & Van Hattum-Janssen, 2007). However, they are able to identify interdisciplinarity, high student motivation and the acquisition of social competences as key characteristics of project-led education (Lima et al., 2007). Classroom discussion is one of the most common strategies that promote active learning. If the objectives of a course are to promote long-term retention of information, motivate students to learn more, allow students to apply information or develop students' cognitive competences, then discussion is preferable (McKeachie, 1987). In learning processes that may be called "traditional", the assessment is mainly an end-of-course process in which the acquired fundamental competence would be the competence to pass the final exam. A more contextualized, autonomous, interdisciplinary and student-centered learning, which is continually assessed, could contribute to a more effective learning process (Freeman et al., 2014; Prince, 2004). During the last decade, it has been recognized that students must engage in their learning process with a student-centered approach that the work of interdisciplinary projects can provide (Mesquita et al., 2013). There are several reasons behind the shift from "traditional learning" to project-oriented higher education (Helle, Tynjälä, & Olkinuora, 2006). For professional reasons: learning must be more work-based and work-oriented. Students not only reinforce and create new knowledge, but also develop competences that are recognized by employers as important tools for professional practice transversal competences (Mesquita et al., 2013). The promotion of critical thinking may be a second reason to embark on a shift to project-based learning (De Graaf & Kolmos, 2003) approaches in comparison to traditional engineering curricula. PBL models seem to inspire a greater degree of involvement in study activities and, consequently, a higher level of understanding.

This study is focused on the students' perception on the impact of innovative teaching learning in the development and assessment of competences focused on people. In this way, the objective is to show the teaching-learning perceptions promoted by the courses through active methodologies.

2 Project-Based Learning (PBL)

Project based learning (PBL) was introduced in the preparation of students for the engineering professions since the 1970s (Christie & de Graaff, 2017). Project-based learning (PBL) is widely regarded as a successful and innovative method for engineering education (De Graaf & Kolmos, 2003).

In essence, the two pedagogical variations of the PBL model have existed for thousands of years. Confucius and Socrates (500 BC and 400 BC, respectively) believed in stimulating learning rather than transmitting information. Socrates is famous for his dialogues that started with a problem and forced students to think, question and seek solutions. Confucius gave his students a jigsaw puzzle room, and if his students could not return with the other three quarters, he would not continue his lesson. One of the earliest and best known varieties of PBL is the form that was introduced at the Faculty of Health Sciences at McMaster, a Canadian university in 1969. It was soon adopted elsewhere, including the medical colleges of the University of Limburg in Maastricht, Holand University of Newcastle, Australia, and the University of New Mexico in the United States. About the same time, Project Based Learning was developed in Roskilde and Aalborg in Denmark (De Graaf & Kolmos, 2003).

Today, the PBL is a worldwide phenomenon in higher education (Christie & de Graaff, 2017). A good example is the case of the University of Aalborg, which practices problem-based learning since 1974 (de Graaff & Kolmos, 2007). In Aalborg, the physical layout of learning spaces (project rooms) across the campus is suitable for that specific brand of PBL (Christie & de Graaff, 2017). However, assessment methods should be compatible with the learning process objectives. With PBL this means testing the progress to establish knowledge and competence test rather than isolated factual knowledge. On the other hand, assess portfolios and project reports are necessarily subject to more qualitative issues, and designing reliable methods with ranking and assessment can be difficult.

An effective approach is to identify aspects of the product or presentation to be evaluated (eg, to classify project or laboratory reports, aspects such as technical strength, organization, depth of discussion, writing quality), select a weighting factor for each aspect, and construct a rubric - a form in which the evaluator assigns numerical rankings for each specified aspect, and then uses the specified weighting factors to compute an overall rank (Felder & Brent, 2003). For example, some possible assessment tools: student surveys, individual and focus group interviews; self-analyzes, learning records, periodicals; peer reviews, self-assessments; written tests or test items clearly linked to the learning objective; written project reports; oral presentations (live or on video); research proposals, problems formulated by students; written criticisms of documents or oral presentations; assessment techniques in the classroom and so on (Felder & Brent, 2003).

3 Methodology

The main objective of this work is to analyse how two courses of the Master of Engineering Project Management (MGPE) of the University of Minho, which are focused on the areas of communication management and human resources management, have contributed to the development and assessment of competences focused on people, through Project-Based Learning (PBL) and portfolios.

The International Association for Project Management (IPMA) defined the Individual Competency Baseline (ICB) as a competency structure and established the definition of the term competence as the application of knowledge, competences and abilities. Each individual has to have a specific set of competences to successfully work in projects. The individual must have perspective competences that respond to the context of the projects, social competences that respond to the personal topics and project competences that respond to the specific practices of the project management (Table). MGPE's disciplines are focused on the development and assessment of people competences, so they are based on their own competencies.

Table 1. Framework of Competences ICB4.0 (IPMA, 2015)

PRACTICE COMPETENCES (13)	PEOPLE COMPETENCES (10)	PERSPECTIVE COMPETENCES (5)
Project design	Self-reflection and self-management	Strategy
Requirements and objectives	Personal integrity and reliability	Governance, structures and processes
Scope	Personal communication	Compliance, standards and regulation
Time	Relationships and engagement	Power and interest
Organisation and information	Leadership	Culture and values
Quality	Teamwork	
Finance	Conflict and crisis	
Resources	Resourcefulness	
Procurement	Negotiation	
Plan and control	Results orientation	
Risk and opportunity		
Stakeholders		
Change and transformation		

3.1 Context of study

The structure of the MGPE degree was fundamentally based on the Project Management Body of Knowledge (PMBOK) of the Project Management Institute (PMBok, 2013). There are two courses of this master's degree centered on the areas of communication management and human resources management, with emphasis on team management. The main purpose of these courses have been to develop and evaluate people-focused competences (IPMA, 2015) relevant to Project Management practice, through Active Learning and Project-Based Learning (PBL). The courses are based on four teaching and learning moments to promote, encourage, assess and develop such people competence.

- Free project: the students choose, with teachers' moderation, the type of project they are going to develop, the respective context and form of development. In this case, the teacher does not impose the context of the project and focuses on the supervision of the project.
- Pre-defined project: the teacher propose a real context where the project will be developed. For example: follow-up of the team work of a team project in another course/program.
- Teamwork assignments: case studies, presentation of seminars, etc.

- Individual portfolio: students must choose one of the ten people focused competences promoted by the IPMA framework to develop throughout the semester.

3.2 Collection and analysis of data

This paper aims to analyze how these courses have contributed to the development and assessment of people-focused competences through Project-Based Learning (PBL) and portfolios. This study is based on a documentary analysis of 70 portfolios of one academic year of the two courses, and a focus group of 10 students, in order to understand their perception about the impact of different teaching-learning moments.

Considering the purpose of the study, the research design followed a predominantly qualitative approach, focused on data collection techniques and procedures such as documentary analysis and focus group, which allowed to understand student's perception on the impact of different student centred teaching-learning activities. A qualitative approach is predominantly based in data collection techniques such as questionnaires, interviews, focus groups, secondary data, or data analysis procedure (such as categorizing data) that generates or uses non-numeric data (Saunders, Lewis, & Thornhill, 2009). In this study, therefore, it refers to one focus group and documents, including photos and video clips.

This study is based on a Document Analysis of 70 individual portfolios of the 2017/18 academic year of two subjects, and two focus group of 10 students. In the first phase of the study, a detailed documentary analysis of the 70 portfolios was carried out in order to extract and capture information and excerpts pertinent to the objective of the study. This data was structured in a matrix and consolidated. The information was synthesized in questions such as: What is the competence developed in the portfolio by the student? What is the contribution of the courses to the development of competences? Teaching-learning moments? Critical reflection of the courses? How did mobilize the competences developed? Finally, comments and observations. The main purpose of the analysis was to know the students' perceptions and to obtain the first evidences of the moments of teaching learning developed throughout the year.

After analyzing the portfolios, which allowed to extract evidences of the importance of the used teaching and learning strategies, two we focused on the focus group were developed. The focus group is a technique that proposes to investigate an in-depth subject through a collective approach, facilitates moments of interaction and debates in a specific group (Sehnem, Alves, Wilhelm, & Ressel, 2015) values group interaction for generation of data, given that people are encouraged to talk about experiences and points of view on a given topic. The main objectives of the use of the focus group in the context of the study were to understand the students' perceptions about the moments of teaching learning promoted in the courses, emphasizing that they do not derive from a process of "traditional teaching". Students were encouraged to explore their views on the subjects, to present suggestions for improvement, to present difficulties according to their experiences and to give examples of a particular learning situation. The sessions were held in a circular table so that all participants could feel involved in the discussion. The intention with the focus group was to find deeper meanings for the dimensions of analysis, considering the perspectives of these participants.

The process of selecting students for the focus groups was based in two main criteria: volunteers and groups with students from the same academic year. An extended invitation was sent to all of these students via e-mail and it was possible to enroll 11 students, forming two focus groups of 6 and 5 students respectively. Due to time constraints, a student in the 1st focus group could not attend. It should also be noted that all sessions were recorded in audio with the permission of the students. Subsequently, they were transcribed for data analysis. The students were informed of the confidentiality of the information collected, mentioning that the data was exclusively for research purposes.

4 Results

In this study, we present data related to the students' perspectives regarding the development and assessment of people-focused competences, through Project-Based Learning (PBL) and portfolios. The portfolio developed in both courses have slightly different objectives. For the course of the first semester, the purpose is to present a personal reflection articulated with the contents envisioned in the *team and communication management* course, allowing an articulation with contexts of developing projects experienced inside and outside of class.

For the second course, the purpose of the portfolio is to present evidences of development of one of the 10 (ten) people focused competences defined by the IPMA. In both courses, the portfolio format is free and quite diverse. As an example, other forms of development of the portfolios, in the form of newspaper, website, event diary, promotional pamphlet format, board game, letters and etc.

The creativity of the student is developed throughout the semester, it is up to the teacher to show examples, to encourage him to leave their "comfort zone", so that the students will be able to promote and present evidences of competences.

4.1 Impact of teaching-learning strategies

In the data analysis, excerpts were extracted that highlight the teaching-learning structure of the courses, such as the evidences on the impact of teaching-learning strategies and the differentiation of the courses in relation to more traditional strategies. Students show evidence of impact in relation to the use of active learning, which allows for more dynamic, interactive, playful classes, greater student autonomy in the development of projects in real contexts, strong interaction with methodologies used in real contexts of the professional activity of Management of projects, promotes and encourages creativity at all teaching-learning moments and, according to the students, such impacts are not evidenced in so-called "traditional" courses. According to De Graaf and Kolmos (2003) it is a very common experience that students are more motivated and work much more with the PBL model than with traditional teaching methods.

The results also point out that active learning makes classes lighter and livelier, allowing more concentration, interest and student participation in the classroom. (Edström & Kolmos, 2014) that with the PBL, higher levels of motivation, collaboration, communication and collaborative knowledge construction are promoted. The individual portfolios present some evidences related to the impact of strategies (Table 2)Table 2. Evidences related to the teaching-learning strategies.

Table 2. Evidences related to the teaching-learning strategies

Teaching-learning strategies	"Many of the techniques presented can change how we relate to business and personal life, rapport, backtracking and feedback are essential to the leaders we want to become, I will certainly bring those competences to life. "
	"The classes were always very interactive which helped us to be focused and dedicated in the contents taught, always having a team dynamics in order to apply the theoretical content addressed."
	"The methodologies used allowed me to get out of my comfort zone. The methods covered are very pleasant and I feel that I can apply much of what I learned in my profession as a project manager."
	"The work I've done has always made me reflect on my life, both personal and professional, and how I can evolve as a human being. One of the most basic lessons I may have learned here is that communication is the key to everything."
	"The way the course is guided, highlights the importance of content in a very ludic way."
	"We conducted an assessment of a case study in the automotive industry. We fill the Project Model Canvas together. Personally, I really enjoyed this activity, because it was quite informative and didactic. In the future, it will be a tool that I will use. "
	"The way of presenting content made the course lighter and livelier in relation to the more, increasing the desire to learn."
	"The methodologies used made the classes were interactive and captivated by the way they delivered the content, perhaps the most innovative and interesting subjects I've had."
	"I found the approach used in the course unit to be very interesting, focusing mainly on teamwork, but also checking individual competences that are complementary in a group work."
	"During the course we had the opportunity to experience a project environment in practice. Every class has had the opportunity to develop their technical and cognitive competences. "
"The insertion of real contexts is an excellent strategy to do the projects in practice, we live conflicts, interpersonal relations, leadership, communication and other competences developed throughout the real project."	
"The specificity to develop the activities of the context of each student, as an example: building a portfolio, is not only to reach and add all the concepts we learn in the course in the same way that is in the book or slides, but to build your portfolio with their perception, one of the positive factors of this type of methodologies."	

	"The methodologies used by the courses are more enriching for the student than the traditional form of assessment. One of the few subjects we will know is that we will apply 100% of content to personal and / or professional life. "
	"Active methodologies encourage students to discuss and make practical what is presented."
	"Project management tools are passed in a very practical way, portraying real contexts."
	"The teachers looked very good as classes, they were recent practical lessons that actually simulated the principles of project management."

4.2 Competences development

Numerous sections in the analyzed portfolios evidenced the development of people focused competences. These evidences reinforce the positive results of active learning strategies presented in several references. According to (Mesquita et al., 2013) that learning must should be more work-based and professionally oriented, students not only reinforce and create new knowledge, but also develop transversal competences that are recognized by employers. The courses, according to students' views, allowed the development of such competences with some examples of real learning situations illustrated in the portfolios. Moreover, they stressed that courses with so-called "traditional" method classes make it difficult to develop and evaluate competences.

Students have identified a wide range of learning outcomes and processes. They said they learned how to engage in teamwork and how to collaborate with colleagues. Peer interaction emerges as a source of motivation. Conflict management is also considered one of the greatest lessons learned. The main competences that show evidences of development were teamwork, communication, conflict management and interpersonal relationships. Table 3 shows some excerpts from the portfolios summarizing the evidence of the contribution of the courses to development and assessment of competences.

Table 3. Evidences related to the development of competences

Development of competences	"I intend to use all the knowledge acquired in my daily life and professional career whenever possible."
	"It was of utmost importance for my personal and professional development, developing my competences in communication and teamwork."
	"I was able to more easily make an introspection of all the changes and implications that the change in communication has had in my life. It has changed my posture relative to others, allowed me to learn to listen and speak before there is a "snowball" " .
	"Today I recognize that through the development of people and the relationships among team members, success will come."
	"As far as the execution of the team work outside of the classroom environment, allowed the development and the fomentation of my creativity.
	"I was able to make an introspection of all the changes and implications that the change in communication has had in my life. It has changed my posture relative to others, allowed me to learn to listen and speak before there was a communication failure and allowed me to perceive that we all have different perceptions of situations within a group, and that it is therefore necessary that these tools and techniques be embraced and used by all, to increase overall performance.
	"I acquired several tools for my life as a future team manager, and it was a great form of self-knowledge."
"Having the company of a team, where many are inexperienced, with different nationalities, running behind, seeing who will help, building the project where we ourselves are managers is fundamental to the development of competences."	

4.3 Competences assessment

Assessment of and for learning are promoted throughout the semester. As an example, at the end of each presentation, teachers assess the learning process, give written feedback and ask for written feedback from other students. One purpose of this type of assessment is that all students are simultaneously evaluated and evaluator. In this assessment process the teacher performs his / her feedback and deliver considerations to the team or student. According to (Christie & de Graaff, 2017) PBL has the ability to revitalize and stimulate higher education and provide an authentic assessment of learning in real life.

The evidences of assessment of competences are closely linked to the development of competences. Thus, it is worth emphasizing that the evidences regarding assessment competences were basically related to the importance of feedback throughout the learning process and auto evaluation. Table 4 show evidences of self-evaluation and of feedback as being truly effective for the learning process

Table 4. Evidences related with the assessment of competences

Competences Assessment	"I was not expecting such a development in such a short time."
	"It is a competence that I still have to deepen, but that during these months was stimulated."
	"With the assessment of competency in feedback form, I can have a clearer view of the way forward to develop my competence."
	"As a final result of the portfolio, we have had both feedback from teachers and from course colleagues. Even from ourselves, we made ourselves review and see the applications of what we have learned, by way of facts."
	"I was able to make a general overview about all my activities during the semester, as well as the knowledge acquired throughout the year."

5 Conclusions

As a result of the study, there were evidences about the impact on teaching and learning promoted by the disciplines, which in fact, portrayed as a differentiation in relation to the so-called "traditional" learning. The specificity to develop the activities in the context of each student (development of an individual portfolio), the insertion in real project contexts]

and a strong interaction with methodologies used in real contexts of the Professional activity of Project Management, stimulating the creativity, were the main impacts on teaching and learning promoted by the disciplines. However, students have identified a wide range of outcomes and learning processes. They said they learned how to get involved in teamwork and how to collaborate with colleagues. Peer interaction emerges as a source of motivation. Conflict management is also considered one of the greatest lessons learned.

The importance of the structure of the courses is highlighted, with notary engagement and participation in the classroom and a higher attendance rate and enthusiasm in the development of the promoted activities. As a recommendation, students emphasize the willingness / desire that other courses seek to employ active methodologies and, thus, promote greater excellence in teaching-learning.

Finally, through examples it was possible to demonstrate the mobilization of the competences developed in the courses, the teamwork, communication and management of conflicts, were trained and improved in the professional environment.

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7 References

- Christie, M., & de Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. *European Journal of Engineering Education*, 42(1), 5-16. doi:10.1080/03043797.2016.1254160
- De Graaf, E., & Kolmos, A. (2003). Characteristics of problem-based learning. *International Journal of Engineering Education*, 19(5), 657-662.
- de Graaff, E., & Kolmos, A. (2007). History of problem-based and project-based learning. *Management of change: Implementation of problem-based and project-based learning in engineering*, 1-8.
- Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European journal of engineering education*, 39(5), 539-555.
- Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET engineering criteria. *Journal of Engineering Education*, 92(1), 7-25.
- Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23), 8410-8415. doi:10.1073/pnas.1319030111

- Hansen, P. H. K., & Luxhøj, J. T. (1995). Engineering Curriculum Reform at Aalborg University. *Engineering Education*.
- Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education—theory, practice and rubber sling shots. *Higher Education, 51*(2), 287-314.
- IPMA. (2015). Individual competence baseline for project, programme & portfolio management. Zurich: IPMA.
- Le Boterf, G., & Garrido, M. D. (2005). Construir competências: individuais e colectivas: resposta a 80 questões.
- Lima, R. M., Carvalho, D., Assunção Flores, M., & Van Hattum-Janssen, N. (2007). A case study on project led education in engineering: students' and teachers' perceptions. *European journal of engineering education, 32*(3), 337-347.
- McKeachie, W. J. (1987). Teaching and Learning in the College Classroom. A Review of the Research Literature (1986) and November 1987 Supplement.
- Mesquita, D., Lima, R. M., & Flores, M. A. (2013). Developing professional competencies through projects in interaction with companies: A study in Industrial Engineering and Management Master Degree. Paper presented at the Proceedings of the Fifth International Symposium on Project Approaches in Engineering Education (PAEE'2013): Closing the gap between university and industry.
- Mesquita, D., Lima, R. M., Flores, M. A., Marinho-Araujo, C., & Rabelo, M. (2015). Industrial engineering and management curriculum profile: developing a framework of competences. *International Journal of Industrial Engineering and Management, 6*(3), 121-131.
- PMBok, A. (2013). A guide to the project management body of knowledge (PMBOK guide). *Project Management Institute, Inc.*
- Prince, M. (2004). Does Active Learning Work? A review of the Research. *Journal of Engineering Education, 93*(3), 223-231.
- Sehnm, G. D., Alves, C. N., Wilhelm, L. A., & Ressel, L. B. (2015). Utilização do grupo focal como técnica de coleta de dados em pesquisas: relato de experiência/Focal group utilization as data gathering technic to researches: experience report. *Ciência, Cuidado e Saúde, 14*(2), 1194-1200.