Project Approaches in Interaction with Industry for the Development of Professional Competences

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Abstract

The engineering education involves the development of professional competences. For this purpose, it is necessary to understand the specific engineering field and to identify the specific professional needs of future engineers. Further, it is important to develop the adequate educational approaches that will foster the development of these competences. This paper aims to contribute to identifying the education needs in the field of Industrial Engineering and Management (IEM) based on the professionals perspectives, articulated with internship students and a group of university teachers. It also aims to reflect on two cases of interdisciplinary project approaches of the IEM program at the University of Minho, Portugal, which directly involves the interaction with industrial companies. One of the cases involves courses of semester seven of the IEM program and the other involves four different engineering programs. The triangulation of data from interviews with professionals, focus groups with university teachers and narratives from internship students contributed to identifying competence needs and the contribution of project-based learning in articulation with companies for students’ professional competences development. The analysis of professional needs points to the importance of practicing the professional practice at the level of education and training. Furthermore, the reflection on the results also stresses the relevance of these kinds of approach from the point of view of all the stakeholders, namely students, university teachers and professionals.

Keywords
Project-based learning, professional competences, interaction with industry

1 Introduction

A common definition for Industrial Engineering and Management (IEM), which has being used by authors, is the knowledge area related to the project, improvement and management of systems composed by people, materials, equipment, financial resources, information and energy, which execute production processes for the production and delivery of products and services [1, 2]. From the professional point of view, this means that IEM engineers should be able to tackle a large and diverse set of problems dealing with different knowledge areas and developing their activities both in industrial and service contexts. Most of IEM engineers have to deal in some point of their career with product and process design, product life cycle management, production system design, production management, project management, quality management or maintenance management, considering economic, society and environmental issues [3]. In order to deal will all of these professional activities the engineer must be able to integrate information, materials, resources and persons using adequate knowledge, methods and abilities at each time. This means that engineers need to apply competences, i.e. mobilize knowledge and abilities resources in specific contexts [4]. Further, in the course of the professional activities both technical and transversal competences are needed [5-9]. Technical competences can be seen as the specific competences of the profession in general or even of some specific activity, such as being able to design a production cell with a specific cycle time. Transversal competences may also be referred as soft skills or generic competences, which can be mobilized transversally in different activities or different professions, such as being able to communicate in front of large audiences or being able to work in multicultural teams.
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Developing competences during the education program phase requires that the curriculum and learning methodologies be adapted to that purpose. Moreover, it is not enough to develop learning processes centered in knowledge transfer, but it is needed to go one step further and apply active learning methodologies, peer instruction, problem and project-based learning [10]. In the context of this work, project-based learning emphasizes interdisciplinary teamwork for problem solving, articulating theory and practice during the development of a project [11-14]. This project should be related to a real professional context, or address a real problem. The development of competences requires the application of technical knowledge in practical contexts, which can be produced closer to academic environment or the professional reality. Some examples of training processes closer to a professional experience have resulted primarily from professional placements in the final years of training. In this approach, we do not conveniently explore the possibility of learning the theory integrated with the development of competences, while simultaneously experiencing a professional environment. Some authors have described examples that examine this advantage through internships in the early years [15], or developing projects based on the professional practice [12, 16-18].

Development of projects to address real industrial systems, identifying problems or opportunities of improvement, allows students to dive in professional activities during their initial training period. During this period, university teachers can support the development of competences required for professional activities. The study of the relation between the development of professional competences and the implementation of interdisciplinary industrial projects during the initial training is not sufficiently clear. This paper aims to contribute for the study of IEM required professional competences describing two types of projects with students of the semester seven of an IEM program, and additionally identify links with IEM required professional competences.

2 Methodology

The purpose of this paper is to contribute to Industrial Engineering and Management Education highlighting the importance of practicing the professional practice. This means that the competences that students develop during their engineering program should be aligned with their professional practice and, for that to occur, the learning process also should consider what an industrial engineer is able to do and what being an industrial engineer means. A qualitative approach was adopted in this study. The goal was to identify professional needs for IEM, considering the importance of active learning environments to put students in contact with real problems within industrial contexts. Thus, two case study [19] will be described taking into account the Project-Based Learning (PBL) approaches developed in IEM program at the University of Minho that involves interaction with industrial companies. The study takes into account the perspectives of university teachers and students of IEM program, as well as the perspectives of professionals of this engineering field. For each group of participants a different method was used:

- **University teachers: Focus Group**
  Three focus groups were carried out with ten participants (a group of four teachers and two groups with three teachers). These teachers teach at the IEM program at the University of Minho and were selected considering their different teaching experiences.

- **Students: Narratives**
  The written narratives involved 5th year students of IEM program carried out at the end of the first semester, 2 to 3 months after they have started their final project in industrial environment. They were asked to describe their experiences, focusing on the link between their initial training and their perspective on professional practice. In total, 33 narratives were received.

- **Professionals: Interviews**
  A total of 15 interviews were done with professionals from six different companies. Six of them graduated in IEM program and three are alumni students before Bologna Process. The voice of these professionals are of key importance in this study because of their learning experience in PBL.

Furthermore, document analysis of the reports of the projects was done in order to understand the kind of technical content that the students are able to explore in the interdisciplinary projects in interaction with companies.

Data analysis integrates these methods and focus on three topics that are linked to the following topics:

- Competences that students need to develop during their learning process;
- Reasons why students should develop those competences;
- Strategies that help students to develop those competences within a learning environment.

The triangulation of the methods provides the integration of the data, which implies a deeper analysis of the information collected for this study [20-22].
3 Context of Study
In the context of the analysis of the development of competences with Project-Based Learning methodologies, the authors present two case studies with interaction with industrial companies. Both of these projects are developed in the 7th semester of the Industrial Engineering and Management (IEM) Integrated Master Degree of the School of Engineering at the University of Minho, Portugal. One is totally developed integrating the courses of the 7th semester centered on a IEM Integrated Project (IEMIP) course [23]. The second is an optional project integrating 4 different degrees and is entitled Innovation and Entrepreneurship Integrated Project (IEIP) [24].

3.1 Industrial Engineering and Management Integrated Project
The objective of the Industrial Engineering and Management Integrated Project (IEMIP) is the “Company X production system analysis and improvement proposals”. During the first phase of this project, the teams develop an analysis of the Company X production systems. This analysis could be related to the production system as a whole or part of the production system, depending on the negotiation between the company and the staff coordination team. During the project, students must apply and integrate the contents of the following courses: Production Systems Design; Workplace Ergonomic Study; Integrated Production Management; Information System for Production; Simulation.

Table 1 presents the list of all projects developed during 6 years, involving 15 companies, and 30 teams of 214 students. During these projects, students have project rooms and the support of several teachers from the different courses involved in the project.

<table>
<thead>
<tr>
<th>Year</th>
<th>Companies</th>
<th>Teams</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007_08</td>
<td>PROHS/JSM</td>
<td>4</td>
<td>28</td>
</tr>
<tr>
<td>2008_09</td>
<td>Actaris; Bosch; ETMA; Texal</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>2009_10</td>
<td>Kyaia; Camport; AmiShoes</td>
<td>5</td>
<td>39</td>
</tr>
<tr>
<td>2010_11</td>
<td>Preh</td>
<td>6</td>
<td>40</td>
</tr>
<tr>
<td>2011_12</td>
<td>Bosch, SNA, Irmãos Salgado (textile)</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>2012_13</td>
<td>Bosch, Delphi, SNA</td>
<td>6</td>
<td>49</td>
</tr>
</tbody>
</table>

3.2 Innovation and Entrepreneurship Integrated Project
The Innovation and Entrepreneurship Integrated Project (IEIP) is multi and interdisciplinary, based on the integration of several knowledge areas. A group composed of students of 3 to 4 degrees will tackle a problem, a specific product of a company, looking for solutions or improvements, integrating their knowledge. Further, there is an objective of development of entrepreneurship competences, mainly innovation, ability to make decisions with lack of information and competence to execute and finish the project. Additionally, students have some training hours on the use of patents databases and on presentation of business ideas. Table 2 summarizes the projects developed during 5 years, involving 5 companies and 20 teams of more than 150 students. During these projects, students have project rooms and the support from several university teachers from different areas of knowledge.

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Project objective</th>
<th>Eng. Degrees</th>
<th>Teams</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007_08</td>
<td>PROHS</td>
<td>Improvement of a Sterilizer Bench and its production system</td>
<td>IEM, PE, IEC</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td>2008_09</td>
<td>Petrotec</td>
<td>Value Analysis of the P5000 Fuel Pump</td>
<td>IEM, PE, IEC, ME</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>2009_10</td>
<td>Galp Energy</td>
<td>HotSpot Design Contest of a new outdoor gas heater</td>
<td>IEM, PE, IEC, ME, ARC</td>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>2010_11</td>
<td>Moldartpóvoa</td>
<td>Proposal of a new type of frames using composite materials</td>
<td>IEM, PE, IEC, ME</td>
<td>4</td>
<td>30</td>
</tr>
<tr>
<td>2011_12</td>
<td>Hydracooling</td>
<td>Development of a commercial refrigeration equipment</td>
<td>IEM, PE, IEC, ME</td>
<td>4</td>
<td>30</td>
</tr>
</tbody>
</table>

Degrees: IEM – Industrial Engineering and Management, PE – Polymer Engineering, IEC – Industrial Electronics Engineering and Computers, ME – Mechanical Engineering, ARC - Architecture
3.3 Examples of technical competences developed within these projects

In the context of the IEMIP, students should address the analysis of part of a production system applying contents from several courses (see section 3.1). Further, the teachers from these courses support the teams’ projects during the semester. Even though teachers will not give specific answers, they will give ideas and indications mainly related to their courses. Using this support indication it is expected that, during the project, students’ teams will develop their own ideas, application of contents and solutions. Analyzing the IEMIP projects in relation to specific areas of knowledge:

- Production Systems Design: cycle time, throughput and work in process analysis; waste identification; Kanbans and materials intermediate stock dimensioning; cell design; SMED; 5Ss.
- Workplace Ergonomic Study: focused on the use of several ergonomic techniques, e.g. Ergonomic Workplace Analysis (EWA), aiming to assess risk factors and to present proposals for a correct dimensioning of workplaces.
- Integrated Production Management: development of a scheduling system prototype, modeling several processes and suggestion of improvement of those processes, using Flowcharts and Business Process Modelling Language (BPML); processes like aggregated and Master Production Planning, Production planning levelling, production order release.
- Information System for Production: focused on mass customization support with generic referencing for Bill-of-materials and routing information.
- Simulation: utilization of Arena system for analysis and improvement studies of production systems.

4 Results

The data analysis integrates the perspectives of university teachers, students and professionals, regarding the importance of practicing the professional practice. The results focus on two dimensions that contribute for the main purpose of this study, namely: developing IEM competences (technical and transversal competences) and the contribution of PBL approaches in interaction industrial companies. These dimensions will be described in the following sections.

4.1 Developing IEM Competences

The professional practice demands a combination of several competences to solve problems, which implies not only technical but also transversal competences. For instance, in a meeting the project manager brings the new requirement from the client that has implications on the final product, which put some tension in all of the team members. The project manager needs to deal with this tension, trying to find out a solution that is positive for the client and for the team. This implies a technical approach to achieve the best solution in this situation, but the project manager also needs to communicate with the team to get them motivated and inspired, in order to overcome the problem. This could be a real situation for an IEM professional. Several studies show the importance of competences in professional practice, particularly transversal competences [25]. This is justified by the lack of this kind of competences in graduates’ profiles. In other words, and in general, curriculum in higher education do not promote enough opportunities for students to develop these competences. The standard focus of curriculum in higher education is a technical one, with a content approach that students need to memorize for the exams. There is a lack of opportunities for students to work in teams, to deal with conflicts, to develop communication skills, amongst other transversal competences that are important for their future professional practice. However, what are the competences needed in professional practice? Each area of knowledge demands different competences because the situations are also different. A previous study identified the importance of the competences for IEM professional practice, based on a longitudinal analysis of job offers in Portugal for this engineering field [26].

The following sections present the perspectives of professionals, university teachers and students that highlight some examples of technical and transversal competences for IEM professional practice.

- Technical Competences

The participants in the study highlighted the high diversity of the IEM area. The professionals in this field will be working in industrial or service companies with the objective of improving companies’ performance. With this objective, they will contribute for the reduction of waste of work, time, money, material or energy, taking decisions based on the use of adequate methods.
“Industrial engineers work to rationalize the use of resources (machines, transport systems, tools, informatics, people, workspace, and financial, amongst others) in industrial and services companies, with the objective to improve the overall performance. An industrial engineer aims to remove waste of time, money, material, energy and other resources” Student 23

“(…) analyzing, designing, improving and implementing the business process of an enterprise (…) manage and optimize resources, adapt and use the most recent methods/techniques/equipment of the market, rationalize the processes and making decisions in a unstable and dynamic context” Student 30

In order to perform effectively, it is important to have a systemic view, understanding the whole process, from the suppliers to the customers, including complete materials’ transformation processes and management business processes as well.

“To have knowledge of the whole process; it’s important to be able to have an understanding of the entire production process… in fact, of the whole value chain” Professional 15

“Thinking about a value chain, an industrial engineer can be in almost all phases: in a logistical level, in a production planning level, in the quality control of materials and final products, in planning of machine a maintenance, logistics routes…” Professional 7

Regarding specific IEM activities actuation in IEM industrial environments, some key ideas emerged from the speech of the participants, namely: management, design, planning, control, coordination, execution, and analysis. These verbs are mostly linked to words like production, manufacturing, cells, quality, logistics or maintenance.

“(…) this is an area of planning, coordination of activities, management of customer orders… anything that has to do with planning, organizing; I think that we have potential in this area. I would say, without doubt, that also in the area of production, production planning, design of production lines (…) organization of workstations and layouts (…) develop coordination functions, such as team leaders, supervisors, etc.” Professional 2

“(…) the industrial manager needs to develop management competences, control and supervision of the activities in the industrial area, related with production and planning control, maintenance, quality control and manufacturing. The industrial engineer is involved in monitoring and controlling strategies for the execution of production programs, analyzing and recommending the development of techniques, equipment and devices which provides the best performance, quality and cost of manufactured products” Student 26

- Transversal Competences

The participants in the study reinforced the importance of transversal competences for the professional practice. Considering the professionals’ perspective, transversal competences is what is missing in the graduates profiles and is needed for engineering practice, such as work in teams, ability to deal with the unexpected, communicating with the others in different situations, amongst other kinds of competences that engineering students should develop during higher education.

“(…) I notice a weakness in engineering students in general related with soft skills. It’s very hard to work with people whom are coming out of university because they don’t know how to communicate, how to sell ideas, how to make presentations, how to write; they are not open to criticisms that are made, they are not open to suggestions. (…) Studying Engineering is enough to get an engineering degree but to be an engineer you need to develop competences that, most often, universities don’t give enough attention.” Professional 1

The transversal competences start to be a distinction mark in the professional profile in order to differentiate oneself in the labor market. The following professional personal experience reveals the importance of these competences in engineering practice.
“(…) basically what are going to distinguish the good professionals from the bad ones will be the transversal competences. I speak for myself (…) I easily relate with the people and in the work that we develop is really important that we are able to motivate people to work” Professional 7 (IEM Graduate)

Students, with their first professional experience, also highlighted the importance of some transversal competences and that these competences should be part of the learning process providing students with opportunities to develop them:

“Other issues that are also important in IEM professional practice are creativity, self-expression, be enterprising and proactive (…) these provides that in any industrial environment an IEM engineer be able to solve problems and identify areas for improvement. The industrial environment may change but the way to find out the solutions for different problems always implies creativity and ability to adapt to different realities.” Student 4

“This kind of competences will normally be intrinsic to each person, but there’s no doubt that could be developed during the higher education, in order to provide “weapons” that will be important in the labor market where the interpersonal relationship is essential. I think this should be one of the major focuses over the five-year course” Student 16

Teachers also reported, based on their own experience, the importance of transversal competences for professional practice. However, according to them, teachers do not know the best ways to do it.

“But this is a question that really need to be developed. They [students] have to be prepared to deal with people, because during the internships they often manage small teams; but I also believe that this will not be accomplished with one course… well, eventually it would depend on the way it would be taught.” FG2 Teacher

“How to work this [transversal competences] with the students? Honestly, I don’t know… For instance, considering the written reports, the students do it in teams and, perhaps, they develop it taking into account that one or more students inside the team write better. (…) But there is also a question here: sometimes students are really good when they are dealing with an approach where they know exactly what to do and how to do and with other approaches they don’t like to leave their comfort zone. So, working with these competences is not easy…” FG2 Teacher 3

The question that arises at this point is how to create strategies for students to develop these competences in their learning process? This may be related to the mismatch between universities and the industry. The participants in this study identified the importance of the industry experiences within the learning process to develop technical and transversal competences. Understanding the concepts becomes more meaningful and deeper within a real context, where theory and practice are interconnected.

“(…) the lectures have much more impact from the moment that we know the professional reality. For instance, a course such as logistics or distribution has more meaning and relevance after being in a company, no doubt.” Professional 2

“In fact I have two great experiences that marked me: one when I went to university and another when I left. The company was not what the university taught me and when I left I was not prepared to solve the problems that put me ahead. And I think today we’re doing better, but we still do not do well (…) than I think that this could result because it complements: we [teachers] with the knowledge and them [industry professionals] with industrial practice and students in interaction with these two spheres.” FG1 Teacher 1

“I’m constantly hearing, in the discipline of the 3rd year, a key discipline in the area of their specialty: - Professor, why we do not go to companies? Not that I wouldn’t like it, not that I am don’t understand them, because I myself felt this need as a student, but the problem is getting companies that are willing to receive students who are still in their initial training phase.” FG3 Teacher 3
Students’ motivation is essential for the quality of their learning process and, for that reason students’ needs are related to the lack of real contexts that provide situations similar to the professional practice. In these contexts, students become aware of what kinds of competences they need and also *practicing for their professional practice*.

“I think there’s a lack of case studies involving real situations, exploring the same difficulties that would be faced in similar environments, in order to solve problems that are actually required in the professional practice and not a problem considering only an abstract approach.” Student 15

“(…) is only missing the involvement of more companies, practical cases, visits and, if possible, short internships during the course.” Student 19

### 4.2 Contribution of Project-Based Learning within Industrial Companies

The participants of this study, namely some professionals (IEM graduates) and students, had learning experiences that highlight the contribution of PBL within industrial companies for *practicing the professional practice*. Even professionals that are not directly involved in the PBL recognize that students have been showing a great level of competences in the beginning of their professional training.

“We [IEM program] have the advantage of having a curriculum program focused on projects with companies, projects with other courses, which provides us opportunities, in an academic level, to have a sense of what will be our future in the companies. Whatever is said, having only lectures and exams, does not give us the reality that we are going to live after the engineering course! The labor market is not that! The labor market is precisely projects, work with people who are not from our area of knowledge and concerning that point our IEM program is ahead in relation to other engineering courses or even to other universities” Professional 7 (IEM Graduate)

“When I was doing my internship I didn’t know what my role in the company was (…) and that was the hardest part for me. Now I see them [final students] without that kind of difficulty, perhaps because of the projects they have. They can get to company professionals and easily ask us for information, useful information. (…) So I think that these are indicators that students are being better prepared” Professional 12

“(…) I need to highlight the projects (IEMIP and IEIP) which, in my opinion, are extremely important and make the difference in IEM curriculum. I believe that my formation in IEM would not have been so consistent if I had not participated in these projects.” Student 28

The projects with industrial companies are a powerful experience for students because they provide them with a closer link to their professional context. They have the opportunity to develop their transversal competences, such as teamwork. It is an open-ended project and students work in large teams, so the learning process also implies to deal with different opinions inside the team, managing the conflicts, amongst other issues because it involves working in teams with eight or ten students. Additionally, students also recognized that PBL is an approach that presents advantages when comparing to the more traditional approaches based on preparation for written exams.

“(…) the project is developed in large teams taking into account the potential of each member and this provides opportunities to learn together, fostering the transversal competences development that are so important for the future in professional practice, such as teamwork.” Student 31

“During my formation in IEM program, the learning experiences with more impact, which helped me more so far, were the projects, undoubtedly. I participated in three (one in 1st year and two in the 4th year) that provided me competences and knowledge that any single discipline could provide. I think that this learning approach is an added value for IEM students and is a program that is closer to industrial context. Search data, teamwork, presentation of results, interaction with people with practical knowledge and, sometimes, with a theoretical level higher than ours, is all an added-value that allows us to progress more quickly comparing with the old approach of studying for an exam.” Student 8

For the teachers the main concern is related to technical competences that students should develop because in traditional lectures teachers can provide the contents in their own rhythm. With project-based learning students are
the ones who will pull the contents, they search for information and build the knowledge in order to get resources to help them to make decisions and find out good solutions for their problems. Thus, the students’ engagement is higher and, consequently, the learning is deeper because they are linking theory into practice and creating their own meaning.

“For example: to explain a technique, Kanbans; teaching Kanbans, I can explain and the students can do some exercises and they can even understand the idea, but if all this happen in a real context, the learning process would be different. I was engaged, because I have to look after the information, because I saw how the things work, because I had to ask questions… this is another kind of learning, is a deep learning. As I had the experience, I will do it again easily in another similar situation and this is much more effective than a lecture where I am talking about Kanbans. What I’m saying is, the quality of the technical knowledge that is learned in a project is deeper; perhaps you cannot cover everything, but what you cover is much deeper.” FG1 Teacher 1

“it’s so simple as this: in the context of the disciple, the students weren’t aware about the application of the exercises that I send to do at home or other things (…) and I think that is related to that, the project allows that applicability that they so much want and need” FG3 Teacher 2

For that reason, students recognize the importance of project approaches within formal curriculum. They suggest the implementation of PBL in all semesters of the program and they presented a proposal to develop within their first semester projects in an industrial company context, as in the 4th year projects. Some students believe that it would be better if they have contact with their professional field at the beginning of their learning process.

“The project as a course should be present in all semesters of IEM program, and not only in the 1st and 4th year (…) these was the course more practical and interesting that we had, with an application in a real context, integrated and organized” Student 27

“In my opinion, the project in the 1st year should be also developed in an industrial environment, in order to put the students as soon as possible in contact with the real contexts.” Student 24

5 Conclusion
Employers often criticize the fact that higher education does not prepare graduates to real problems and demands in companies [25], and the engineering practice implies a combination of technical and transversal competences that sometimes are not the focus of engineering programs. These programs are in general focused on technical issues, not providing adequate opportunities for the development of professional competences. This paper looks at the importance of practicing the professional practice as a mean for the development of competences in a way that moves this first phase of engineering education toward the industrial needs.

Findings presented in this study show experiences of learning approaches that create learning situations where students can develop those competences. The results point out the importance of project-based learning (PBL) in interaction with industrial companies for practicing the professional practice. This learning approach creates opportunities to put students inside real contexts, dealing with real problems, where they need to link theory to practice [27]. Within this context, students are developing technical and transversal competences during their training as future engineers and the learning process becomes more meaningful for them [28]. Students recognize the importance of what they learn, and they understand how and why a set of contents are important for their future work as industrial engineers.

The collaboration with industries is also significant for curriculum development in order to get inputs for development of new educational programs or for the revision of existing curricula [29], particularly considering the competences needed for professional practice. Moreover, university programs show that some educational practices are changing and making the difference for students, university teachers and industrial engineers.

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References

