Developing professional competencies through projects in interaction with companies: A study in Industrial Engineering and Management Master Degree

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Abstract

This paper draws upon a part of a research project aiming to analyze curricula elements and competencies related to professional practice, in order to contribute to the improvement of the quality of the training program in engineering courses. Data were collected through a general survey to students, teachers and professionals. This paper focus on professionals' perspectives and the results show the relevance that PBL experiences assumed in professional situations. Four main topics emerged from data, were analyzed, and discussed, namely technical competencies, transversal competencies, curriculum organization and interaction with companies. The results of the professionals' survey point to the relevance of PBL experiences in professional situations. The findings also highlight the importance of project- learning approach for the quality of engineering curriculum and the development of both technical and transversal competencies.

Keywords: Engineering Education; Project-Based Learning; Professional Profile.

1 Introduction

Engineering programs have been based on a strong science and math fundamental knowledge during the first years followed by increased specialized knowledge during the course. This kind of curriculum organization is common in Higher Education Institutions all over the world, because it is related with the engineering profession, which is, according to UNESCO (2010, p. 24), " the field or discipline, practice, profession and art that relates to the development, acquisition and application of technical, scientific and mathematical knowledge about the understanding, design, development, invention, innovation and use of materials, machines, structures, systems and processes for specific purposes.". However, the global changes in the last century (e.g. technological innovations, mobility growth, economic crisis …) have had an impact on engineering education issues. Thus, higher education institutions and professional associations in many countries (USA, Europe, Australia…) have been re-thinking the teaching and learning approaches in engineering courses, including other competencies in curriculum. In addition to adequate contents, the selection and development of adequate competencies, i.e. the ability to be able to use that content in real contexts, have been considered as fundamental dimensions in engineers' training. These competencies are being identified by accreditation boards all over the world, namely by ABET (Accreditation Board for Engineering and Technology), as well as EUR-ACE (European Accreditation Board for Engineering Education) and Engineers Australia. Specific technical knowledge is not enough for engineering professional practice. Other requirements are needed, such as working in teams, leading with unexpected situations, making decisions. Literature refers to these competencies with different terms: "generic", "transferable", "core", "professional", "employability", "soft". In this study the term used is "transversal competencies" which refers to those competencies that are beyond technical subjects but are also related to professional practice. These kinds of competencies are embedded in different situations and are valued, not only in the case of engineering, but also in other areas of knowledge. One of the questions that arise from existing literature is the gap or mismatch between graduate competencies developed during their initial training and the competencies that are required in the workplace. None of these studies integrates the perspectives of students, faculty and professionals. For example, Evans, Beakley, Crouch, and Yamaguchi (1993) present a survey that includes alumni graduates about curriculum program and show the overwhelming support for a broad-based undergraduate program by graduates of all degree programs. The studies of Meier, Williams, and Humphreys (2000), Pascail (2006), Sageev and Romanowski (2001) and Scott and Yates (2002) also include the professionals' perspective that presents the competencies required by the industry. Eskandari et al. (2007) include the perspective of professionals and faculty. Jackson (2012) focus the students' perspective in the study related with employability skills. In general, the results of these studies show that technical and transversal competencies must be considered in engineering curriculum, in order to prepare graduates to the demands of professional practice.

Pedagogies of Engagement (Smith, Sheppard, Johnson, & Johnson, 2005) reinforce the idea that active learning strategies enhance deep level learning, instead of surface learning – Biggs (2007), where students develop competencies related to their professional practice, changing the quality of what they learn, how they learn and why they learn. Project-Based Learning is a learning approach that includes this purpose (Thomas, 2000).

This paper is part of a wider research project that is being developed at the University of Minho, Portugal, since 2010. It aims at analyzing the curriculum elements and competencies related to professional practice, in order to contribute to the improvement of the quality of the training program in engineering courses. The data collection is based on the perspectives, experiences and expectations of students, teachers and professionals about curriculum development, the connection/articulation between initial training and professional profile and competencies related to professional practice. Industrial Engineering and Management (IEM) has been considered a special area of study, namely at the Industrial Engineering and Management Integrated Master program (IEM-IM) at University of Minho as a case study. This course includes the development of Project-Based Learning approaches (PBL) in 1st year, 1st semester and also in both semesters of 4th year. This model was inspired in the Project-Led Education (PLE) work of Powell and Weenk (2003). In this paper the implications of PBL for professional practice will be discussed, considering the data collected in the first phase of the research project aforementioned. A survey was applied to IEM-IM students and teachers, as well to IEM professionals including graduates from IEM-IM.

2 Project-Based Learning (PBL) and Professional Practice

One of the main characteristics of Engineering practice is the design, planning, implementation and evaluation of projects. This implies the inclusion of the concept "project" in the curriculum as mandatory. During the last decade it has been recognized that students should engage in their learning process with a student-centered approach that interdisciplinary projects work can provide. For example, a common finding arising from several studies in USA, where an integrated curriculum was developed in the first year of engineering courses, indicates that students' motivation increased and their retention decreased (Al-Holou et al., 1999; Froyd & Ohland, 2005; Pendergrass et al., 2001). This can be justified by the integration of several engineering contents and experience early in the curriculum, based on real projects that students need to develop (Dym, Agogino, Eris, Frey, & Leifer, 2005). Thus, Project-Based Learning (PBL) in engineering curriculum is considered as an added value for students learning and it is also recognized as an effective way to prepare students for professional practice (Helle, Tynjälä, & Olkinuora, 2006; Jollands, Jolly, & Molyneaux, 2012; Litzinger, Lattuca, Hadgraft, & Newstetter, 2011; Mills & Treagust, 2003; Prince & Felder, 2006).

PBL is defined as a learning approach that "provides students with the opportunity to bring together knowledge-based skills from a number of subject areas and apply them to real-life problems" (Dickens & Arlett, 2009, p. 268). The learning principles of PBL may be categorized in three principles (Graaff & Kolmos, 2003): 1) learning approach, as the learning process is organized around problems and is carried out in projects; 2) contents approach it is a central principle for the development of motivation, and the nature of the problems implies the focus on interdisciplinary, because typically engineering problems involve different subjects. In addition, students can also establish a link between theory and practice; 3) and collaborative approach highlights the team learning aspect underpinning the learning process as students have the opportunity to learn from one another and also to learn by sharing knowledge and ideas in a collaborative learning process. When the projects have companies involved the students' motivation increases and the learning process is deeper. For students working in a context of real companies they apprehend the subject content based on the data information received and they also perceive the industrial processes, how a company operates and where students can experience the relevance of content developed in the classroom has in real practice (Lima, Fernandes, Mesquita, & Sousa, 2009).

Within a learning process based on a deep approach (Prosser & Trigwell, 2000) students not only reinforce and create new knowledge, but they also develop competencies that are recognized by the employers as important tools for professional practice – transversal competencies. Several studies show the mismatch in graduates' profile which has been identified by employers (Jackson, 2012; Markes, 2006; Martin, Maytham, Case, & Fraser, 2005; Mason, Williams, & Cranmer, 2009; Nair, Patil, & Mertova, 2009; Stiwne & Jungert, 2010; Tymon, 2011; Walther, N.Kellam, Sochacka, & Radcliffe, 2011). PBL provides learning contexts, situations and spaces where students are able to develop transversal competencies, namely teamwork, communication skills, planning and organization, project management, creativity, decision-making (Dym et al., 2005; Hattum-Janssen & Mesquita, 2011; Jollands et al., 2012; Mesquita, Lima, Sousa, & Flores, 2009; Thomas, 2000). Thus, PBL is a learning approach that enhances a better preparation for professional practice. Dym and their colleagues state that: "PBL does address one of the key issues in the cognitive sciences, *transfer*, which may be defined as the ability to extend what has been learned in one context to other, new contexts" (2005:110).

3 Methodology

This study takes into account the perceptions of IEM professionals about their learning process. Data were collected through an online questionnaire that was sent to 127 IEM-IM professionals graduated between 2007 and 2011. A total of 49 responses were received, which represents a return rate of 39%. The survey was conducted during three months (April to June 2012). The questionnaire included three dimensions: 1) issues related to IEM professional profile (technical competencies, transversal competencies and features regarding engineering practice); 2) the articulation between initial training and professional practice; 3) and suggestions for curriculum improvement. Open-ended and closed questions were included. The former were subject to content analysis and the latter were analysed using SPSS (Statistical Package for the Social Sciences), version 20.0. Open-ended questions were analysed through content analysis based on a categorization process (Bardin, 1979), taking in most cases an inductive approach (Esteves, 2006).

4 Findings

In this paper, we present data related to professionals' perspective in regard to professional competencies through projects in interaction with companies. In the data analysis four categories were identified: technical competencies; transversal competencies; curriculum organization and interaction with companies.

4.1 Technical competencies

Professionals' responses point to areas of knowledge that initial training has provided them but also other areas that professionals recognize as important to be developed further in curriculum at Higher Education (see Table 1). Production Management in curriculum was seen as added-value for professional practice, namely subjects related to Lean Manufacturing. Also identified was the general approach of Industrial Engineering and Management program. In fact, IEM is an engineering field that integrates the notion of diversity and flexibility and curriculum programs can be characterized by these features, because they focus on different areas of knowledge (Lima, Mesquita, Amorim, Jonker, & Flores, 2012). Economics Engineering appears in both sections, which means that is an area highly valued in the curriculum. However, the participants state that it is not enough. Similarly, other areas seem to be needed, particularly Computer and Information Systems.

Table 1: professionals' perspectives about technical competencies

Added-Value of initial training for professional practice			Suggestions for curriculum improvement		
Subjects	f	Quotes	Subjects	f	Quotes
Production Management	2	"Lean techniques" "technical competencies in issues of production management"	Computer and Information Systems	3	"Advanced Excel classes in the PC1 (computer programming) course" "inclusion of contents on management software (e.g. SAP)"
Economics Engineering	1	"Mathematical aspects (...) cost analysis"	Economics Engineering	1	"More comprehensive aspects of accounting / economics"
Industrial Engineering and Management	1	"Knowledge of tools and techniques of several areas (quality, production, process ...)!"	Project Management	1	" invest on project management"
			Other	2	"Gaps in the area of mechanical engineering, related to mechanics of equipment, processes related to welding and materials" "inclusion of contents about transformation processes more common in industry (metal, polymers, etc.)"

4.2 Transversal competencies

As far as transversal competencies are concerned, Table 2 summarizes the perceptions of the participants. Teamwork experiences developed during initial training have had particular relevance for professional practice. Professionals had the opportunity to develop these competencies because curriculum covers Project-Based Learning approaches. In this context students developed other competencies related to teamwork and leadership. Data also show that leadership is one of the transversal competencies identified as an issue for curriculum improvement. One of the competencies more emphasized by professional was foreign languages, namely English and German. This is consistent with other studies, especially when English is not the mother tongue (Stiwne & Jungert, 2010). Other competencies were identified, but with less relevance: team management, motivation and conflict management that are related to teamwork; working with information required for IEM practice, because engineers deal with a great deal of information in the companies; and entrepreneurship which is essential to respond to economic crisis. For instance, in

Europe many industries are closing down and IEM is also changing their scope (e.g. services). For this, critical thinking is required in order to question what is needed and how it is possible to accomplish what is needed.

Table 2: professionals' perspectives about transversal competencies

Added-Value of initial training for professional practice			Suggestions for curriculum improvement		
Subjects	**f**	**Quotes**	**Subjects**	**f**	**Quotes**
Teamwork	8	"(with the) implementation of several projects it was possible to work in groups" "group work, leadership within groups and motivation for the completion of the work"	Foreign Languages	9	"should be compulsory at least one foreign language during the course" "Introduction of foreign languages, especially English and German"
Critical Thinking	1	"Ability to question and not resign myself to absolute truths"	Leadership	5	"Develop more aspects related to leadership, how to build high performance teams"
			Team Management	2	"Courses in leadership and team management"
			Entrepreneurship	1	"encouraging the creation of self-employment"
			Working with information	1	"working with large amounts of information"
			Motivation Strategies	1	"... techniques of motivation and leadership"
			Conflicts Management	1	"Technical English, conflict management, team management, leadership"

4.3 Curriculum Organization

Issues related to curriculum organization also emerged from the data (see Table 3). For 14 professionals, PBL was an important learning experience for their professional practice because it related to real contexts and students could develop transversal competencies that are also required in the workplace. Some professionals agreed that PBL should be included in the 3rd year of the course. Additionally, they also suggested more *Practicum* in curriculum, in order to get a closer experience to professional contexts (Zabalza, 2009) and practical work. Other issues related to the relevance of some subjects such as Economics Engineering (more relevance in the curriculum) and Basic Sciences (less emphasis in the curriculum). Other indicators related to curriculum organization were identified. The experience of IEM areas in an early stage of the course was highlighted, because first year in engineering could be critical for students' motivation (Froyd & Ohland, 2005).

Table 3: professionals' perspectives about curriculum organization

Added-Value of initial training for professional practice			Suggestions for curriculum improvement		
Subjects	**f**	**Quotes**	**Subjects**	**f**	**Quotes**
Project-Based Learning (PBL)	14	"PLE experiences (...) show that the theory differs somewhat from practice and encourage students to seek new approaches that go beyond what is taught in class" "The project teaching methodology has the enough gains in the development of competencies that the market demands"	Practical Approaches	8	"Database, logistics, CAD / CAM are good examples of courses that should have a more practical component" "liked to have had the opportunity to develop more practical work in specific areas of the course"
Practical Lessons	1	"practical classes"	Relevance of the subjects	5	"a higher load of courses related to economics / management instead of disciplines of Mechanical Engineering" "transforming courses of computer programming, physics, calculus to optional (...) until today I did not take advantage of them "
International Experiences	1	"Participation in the Erasmus program"	Project-Based Learning (PBL)	3	"introduction of a PLE (project-based learning course) in 3rd year" "continue to work with companies (PLE)"
			Practicum	2	"model of short work placements along the course (mainly from the 3rd year)"
			Other Issues	4	"greater contact with the IEM area in the 1st and 2nd years" "ensuring that the programs taught are updated"

4.4 Interaction with companies

The last category focuses on the interaction with companies (see Table 4). The participants also highlighted the *Practicum* (Zabalza, 2009) in fieldwork, visits to companies and working with real data to apply the content provided in the classroom. This could be made through PBL, as mentioned by one of the professionals.

Table 4: professionals' perspectives about interaction with companies

Added-Value of initial training for professional practice			Suggestions for curriculum improvement		
Subjects	**f**	**Quotes**	**Subjects**	**f**	**Quotes**
Practicum	10	"Visit companies and develop fieldwork" "Work carried out in companies (actual data rather than case studies)" "Interaction with companies to develop real jobs"	*Practicum*	16	"greater interaction between academia and industry" "try a higher integration between companies and the academic content, make more visits and work directly with the companies in order to develop more practical concerns" "continue to focus on the interaction between the course and industry through projects"

5 Final Remarks

Findings presented in this paper show that there are four main topics in the professionals' perspectives, namely technical competencies, transversal competencies, curriculum organization and interaction with companies. Transversal competencies were more highlighted than the technical ones by the professionals. This does not mean that transversal competencies are more important than technical ones. Perhaps, traditional curriculum is more focused on technical aspects and professional practice implies both. In this sense, "non-technical skills cannot be taught isolated from the technical context in which they will be used. Integrated projects are a crucial tool for achieving such ends" (Martin et al., 2005, p. 179).

According to data, teamwork experiences within PBL were very useful for professional practice. Working in teams is one of the focuses in project approaches and, consequently, is part of the learning process (Powell & Weenk, 2003). PBL provides students with knowledge and competencies for their professional practice. Nowadays, engineers need to work in multidisciplinary teams (Martin et al., 2005) and in multicultural work environments (Nair et al., 2009).

This purpose is recognised by the participants in this study. They suggest developing PBL throughout the course reinforcing the participation of companies in the projects. The interaction with companies is very valued by the participants. Findings show that the interaction between university and companies is a key issue for curriculum improvement. There is a lack of studies that explore this approach. It is not easy to accomplish but it is definitely needed for the successful development of competencies (Markes, 2006).

It is possible to conclude that the most important learning experiences were related to Project-Based Learning (PBL), as well as the opportunities to interact with industrial companies in real projects. This may be considered as an important contribution for Engineering Education. Studies related to PBL focus on the analysis of the experiences (benefits and limitations for learning, challenges for staff, etc.) and the perspective of graduates are not usually looked at. This study suggests the relevance of PBL for professional practice and adds to existing studies which show the importance of this learning approach for the quality of engineering curriculum.

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