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Industrial Engineering and Management Curriculum Profile: Developing a Framework of Competences

Diana Mesquita
Institute of Education, University of Minho, Campus of Gualtar, 4710-057 Braga, Portugal – diana@dps.uminho.pt
Rui M. Lima
Dep. of Production and Systems, School of Engineering, University of Minho, Campus of Azurém, 4800-058 Guimarães, Portugal– rml@dps.uminho.pt
Maria A. Flores
Institute of Education, University of Minho, Campus of Gualtar, 4710-057 Braga, Portugal – aflores@ie.uminho.pt
Claisy Marinho-Araujo
InstituteofPsychology, Universityof Brasília, Campus Darcy Ribeiro, 70910-900 Brasília, Brazil – claisy@unb.br
Mauro Rabelo
DepartmentofMathematics, Universityof Brasília, Campus Darcy Ribeiro, 70910-900 Brasília, Brazil – rabelo@unb.br

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Abstract

This paper presents a framework of competences developed for Industrial Engineering and Management that can be used as a tool for curriculum analysis and design, including the teaching and learning processes as well as the alignment of the curriculum with the professional profile. The framework was applied to the Industrial Engineering and Management program at University of Minho (UMinho), Portugal, and it provides an overview of the connection between IEM knowledge areas and the competences defined in its curriculum. The framework of competences was developed through a process of analysis using a combination of methods and sources for data collection. The framework was developed according to four main steps: 1) characterization of IEM knowledge areas; 2) definition of IEM competences; 3) survey; 4) application of the framework at the IEM curriculum.The findings showed that the framework is useful to build an integrated vision of the curriculum. The most visible aspect in the learning outcomes of IEM program is the lack of balance between technical and transversal competences. There was not almost any reference to the transversal competences and it is fundamentally concentrated on Project-Based Learning courses.The framework presented in this paper provides a contribution to the definition of IEM professional profile through a set of competences which need to be explored further. In addition, it may be a relevant tool for IEM curriculum analysis and a contribution for bridging the gap between universities and companies.

Key words: *Industrial Engineering and Management (IEM), Competences, IEM Areas of Knowledge, Curriculum Analysis*

1. INTRODUCTION

The study of the relationship between labour market and universities has been reinforced in international agendas, justified by globalized practices and strategies for approaching the problem of global economic crisis. Considering the example of Europe, the Bologna Process has imposed changes in universities in order to meet the commitment with knowledge, quality and employability. The European Commission issued a document (*New Skills for New Jobs: Anticipating and matching labour market and skills needs*) which shows the concern about this topic: “Education and training systems must generate new skills, to respond to the nature of the new jobs which are expected to be created, as well as to improve the adaptability and employability of adults already in the labour force” [1] Competences are seen as a tool for competiveness in Europe, and educational institutions are responsible to provide opportunities and conditions to achieve them. In this sense, the relationship between universities and labour market should be more integrated linking theory and practice in order to foster the development of competences in higher education vis-à-vis those required by employers and society.

What kinds of competences directly contribute to the expected professional profile? Do the competences that students developed in their initial training relate to the kinds of competences required in their professional practice? In 2012, the European Centre for the Development of Vocational Training issued a report which points to an understanding of skill mismatch based on theoretical and empirical findings from the enterprises' perspective. The report states that: "The capacity of firms to find employees that constitute a good 'fit' for the company depends critically on the ability of education and vocational education and training (VET) systems to respond by imparting to graduates the necessary knowledge, skills, competences and also attitudes" [2]. The report also acknowledges that: "A lack of correspondence between the skills emerging from EU universities and training systems and the demands of EU employers is also likely to affect the competitiveness of the latter" [2]. Existing research literature also discusses the importance of the relationship between competences and professional practice. Findings from existing studies identify the mismatch between knowledge acquired in university and competences demanded by the employers [3-6]. Furthermore, the need to clarify the notion of competency is considered a key element in its application in the curriculum [7, 8].

This paper focuses on a specific engineering branch, namely Industrial Engineering and Management (IEM) which is characterized by a diversity of organizational / industrial tasks and functions. It requires an interdisciplinary approach in curriculum organization bringing together the different areas of knowledge that IEM integrates. This is reinforced by the different labels that are commonly identified within this engineering branch: Industrial Engineering, Manufacturing Engineering, Engineering Management and Production Engineering are few examples. This diversity impacts on the design of curriculum programs. A European project called Industrial Engineering Standards in Europe (IESE) aimed to analyse and compare Industrial Engineering Educational Programs (IEEP) in different countries and then used those findings to identify the gap between the programs and the industrial needs. The results revealed that "the current Industrial Engineering education programs being offered in the three countries surveyed are not adequate in meeting the current needs of industry" [9](pp.13). This idea is consistent with other studies in Spain [10], USA [11] and in New Zealand [12]. A curriculum review based on teaching and learning best practices is then needed.

This paper aims at developing a conceptual framework that can be used as a tool for curriculum analysis and design, including the teaching and learning processes and the alignment of the curriculum with the professional profile. The framework is based on the analysis of curriculum elements and professional competences in IEM courses, contributing to the improvement of the curriculum programs in engineering courses. IEM has been considered a special area of study, in this case the Industrial Engineering and Management Integrated Master program (IEM-IM) at University of Minho, Portugal.

The framework will be presented in the following sessions, considering the process of its development, followed by the application of the framework to the IEM-IM curriculum.

2. DEVELOPING A FRAMEWORK OF COMPETENCES

Drawing upon existing studies, the development of the framework was carried out according to the IEM professional profile as well as and the competences that contribute to its development within existing curricula. This was conceptually supported by previous work developed with the intention to create assessment models related with professional practice competences (Marinho-Araújo & Rabelo, 2013; Rabelo & Soares, 2011; Marinho-Araújo, 2004). The work presented in this paper expanded this approach by developing a framework to represent the articulation between IEM knowledge areas, IEM competences and IEM curriculum (see **Figure 1**). In order to create the necessary articulation between these dimensions a combination of two methods of data collection was used: document analysis and a survey. The ways in which the data were mobilized for the development of the framework will be described in the next sections.

2.1 Characterization of IEM knowledge areas

IEM knowledge areas include an understanding of IEM as an engineering field, which is important to identify the competences that are needed to professional practice. The UNESCO Report for engineering addresses the issues, challenges and opportunities in engineering practice [13]. The importance of a better understanding of what engineering is and what engineers do is also highlighted in the document.

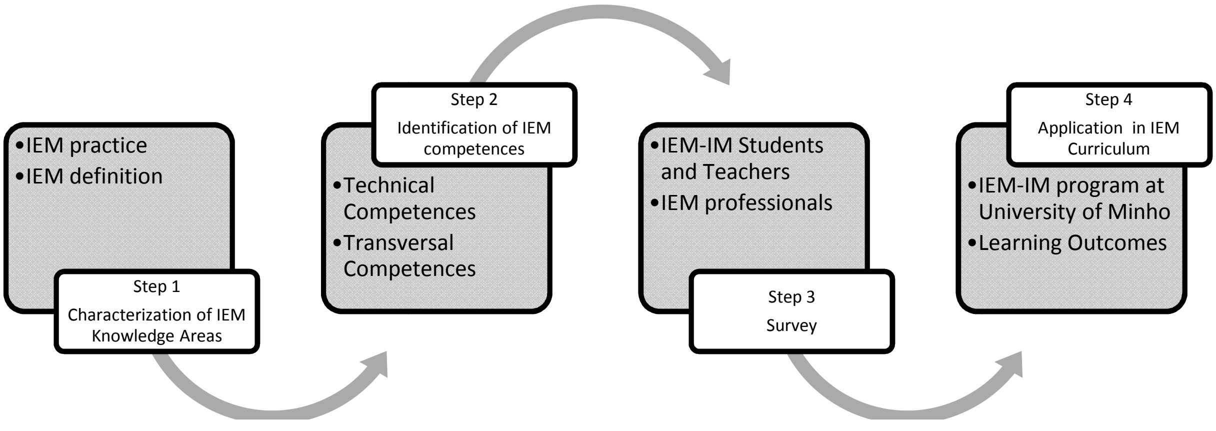

Figure 1. An overview of the development of the framework of competences

Thus, the characterization of IEM knowledge areas include an understanding of IEM as an engineering field, as well the practice of industrial engineering. To collect data related to this topic a document analysis was done based on the sources listed in **Table 1**.

Table 1. Documental Analysis related to IEM Background – type of sources, documents and type of information collected

Questions about Industrial Engineering and Management (IEM): What does an IEM engineer do? What is IEM? What is the purpose and evolution of IEM?	
Source	**Type of Information**
Professional Associations: Institute of Industrial Engineering (IIE) Brazilian Association of Production Engineering (ABEPRO) Association for Operations Management (APICS) Institute of Industrial Engineers is the Australia Institute for Operations Research and the Management Sciences (INFORMS) Asia Pacific Industrial Engineering and Management Society (APIEM) International Association of Engineers (IAENG) Indian Institution of Industrial Engineering European Institute of Industrial Engineers	IEM definition and professional approach The role of industrial Engineering IEM areas of knowledge
Maynard's Industrial Engineering Handbook	IEM evolution and historical context The role of industrial Engineering IEM areas of knowledge

The diversity within IEM field raises some difficulties to get to a common understanding about what is IEM. It is a recent area that has been growing since the 1960s. It has evolved over the last century, innovating in relation to new technologies and tools useful for business / industrial organizations' competiveness. Combining different sources [14, 15], a definition of IEM was identified as it is seen as an engineering field related to the project, improvement and management of systems composed by people, materials, equipment, financial resources, information and energy, that deliver products and services.

Traditionally, the functions related to IEM were associated with manufacturing process, but, over time, industry and society have been showing other types of needs that encouraged IEM intervention in other sectors of activity, such as "financial services, both in new product development and process improvement; distribution and logistics services, particularly through the development of new software and operational modelling, analysis, and design capabilities; government services; and many segments of the growing worldwide market for information services and technology" [16].

The possibility of several applications in industry makes IEM an interdisciplinary field including a variety of knowledge areas. A recent project carried out in Europe focuses on the Industrial Engineering Standards (IESE) to analyse and compare curriculum programs of six different European countries. The model used points out seven areas of knowledge: Engineering Basis, Industrial Engineering Fundamentals, Operations Research, Manufacturing Systems Engineering, Management Systems, Human Factors Engineering, Innovation and Technology and Environment/Sustainability [9]. These areas were defined in a broader sense, but all of them contain "items" that include even more areas. For instance: Management Systems integrate nine items, such as Project Management or Quality Management. In a previous work Lima, et al. [17] considered a classification based on aggregated knowledge areas and additionally presented specific IEM knowledge areas, which were also used to analyse curriculum programs in four universities in Europe. The aggregated knowledge areas were "Basic Sciences", "Economics and Management", "Engineering Sciences" and "Industrial Engineering and Management". A key characteristic of this work was a detailed and specific analysis based on 13 specific IEM knowledge areas. This was the typology that was used in the framework:

1. Production Management (including Production System Design)
2. Automation
3. Quality
4. Economics Engineering
5. Operations Research
6. Computer and Information Systems
7. Ergonomics and Human Factors
8. Logistics
9. Maintenance
10. Project Management
11. Sustainability
12. Product Design
13. Simulation

2.2 Characterization of IEM competences

Considering the fact that IEM entails a wide variety of multiple areas of knowledge, the IEM engineer has to play diverse roles, and he/she is highly affected by other functions and departments inside the enterprise and may also contribute at any point and any level in enterprise system. This scenario entails quite complex situations because it requires the mobilization of highly diverse areas of knowledge to be applied in practice. Accordingly, Billings, et al. [18] identified eight key success factors to IEM engineer's role: 1) be flexible, but focused; 2) apply industrial engineering concepts to real-world problems; 3) understand the "big picture" –

how change initiatives impact the overall organization; 4) understand and analyse the current processes accurately; 5) manage change; 6) follow through on implementation; 7) be creative; 8) communicate clearly. Hence, these factors must be considered in IEM professional profile, by developing competences that graduates need to acquire and develop in their initial training program. For this reason, “competence” is the key element in the framework. Considering the characterization of IEM knowledge areas evidence was collected in order to identify IEM competences that will be presented in the next sections.

First, the clarification of the concept “competence” was discussed, considering the different perspectives embedded in the literature. Terms such as objectives, abilities, and performance are sometimes considered synonyms with competences and this is often the reason for the unclear perception of its real meaning. The key-word “mobilization” is what makes the difference between the term *competence* and the other concepts. In this sense, competence encompasses the mobilization of resources (with respect to knowledge and its application, previous experiences, values and beliefs) in specific contexts (e.g. academic or professional). A competence always refers to persons [19] and lies on how to mobilize the resources in a situation or a problem [20, 21]. For that reason, it cannot be reduced to a status or a knowledge to be acquired [22], but it has to be represented in a context where competences are materialized. According to Stoof, et al. [23], “a definition of competence should be adequate for the situation in which it is being used”. Thus, an understanding about the context or situation is quite important for an understanding about what competences people need to develop. An activity developed in a specific context, depending on its complexity, may require a combination of several competences. For example: conducting a project meeting implies communication skills (negotiation, listening the others, explaining ideas and presenting an argument…), specific knowledge about the project, knowing the team members, etc. Plus, some authors describe the competences according to its nature such as technical, methodological, social and participative competences [24]; general, specific and basic competences [25]; individual and collective competences [19]; in Higher Education European Area, competences may be distinguished as subject specific and generic ones [26].

Within the framework two categories of competences were used. The first category is called “technical competences” and is related to professional practice and strongly linked to the areas of knowledge. The second category is “transversal competences” and is associated with dimensions relevant for any field, occupation or context, either professional or personal. Considering the diversity of IEM areas of knowledge, this classification need to be broad enough, in order to allow the analysis of different contexts, functions and activities in IEM practice.

The data collection to identify the IEM competences was organized taking into account several documents, in order to get indicators to select and define them (**Table 2**). The information collected in the previous step (see **Table 1**) brings inputs for the definition of the competences because is quite related with IEM practice. Furthermore, other sources were added in order to get an in-depth perspective of the most valued competences.

Table 2. Documental Analysis related to Competences – type of sources, documents and type of information collected

Questions about IEM Competences: How can competences be defined? What are the most valued competences by the Accreditation Engineering Programs? How can the practice of engineering be characterized?	
Sources	**Information**
Engineering: UNESCO Report on Engineering The Engineer of 2020 – Vision of Engineering in the New Century	Characteristics of engineering practice Challenges for an Engineer 2020 Aspirations and Attributes of Engineers of 2020
Bologna Process: Dublin Descriptors Framework of Qualifications (FQ-EHEA) Tuning Report	Learning Outcomes Competences Definition Technical Competences Transversal Competences
Accreditation Boards: Accreditation Board for Engineering and Technology (ABET) – USA European Accredited Engineering Programs (EUR-ACE) - Europe	Standards for the Accreditation of Engineering Programs

The selection of the competences was based on a process based on all documents collected. The information was analysed considering the dimensions that were defined (technical and transversal competences) and the items most cited were included in a list of competences. Then, the selection was refined considering the recent literature, the insights of specialists and the survey. The scope of this process was bounded by the case of study, i.e. A list of 8 technical competences and 11 transversal competences was achieved at the end of the analysis. Some competences were conclusive. For instance, “teamwork” is present in almost all documents. Other competences were not included. For instance, “teaching / developing others” is mentioned by *Maynard’s Handbook* but was not included in the list, because are neither referenced by other sources, neither by specialists nor emerged from the survey.

2.2.1 *Technical Competences*

The technical competences were defined considering the flexibility desired for the framework. Thus, there is a connection and progression between analysis, design, project, planning, implementation, control and improvement, which is also present in the current understanding of IEM (section 2.1). For that reason, these competences are closely linked to the areas of knowledge. Considering this approach, the framework presents eight IEM technical competences (TC):

TC1. Production systems analysis and diagnosis

TC2. Production systems design / Production Planning and Control processes design

TC3. Planning production and project processes

TC4. Monitoring and Controlling processes and production system performance

TC5. Developing projects, implementing systems, applying methods and procedures

TC6. Evaluating production systems and processes

TC7. Describing, comparing and selecting technologies, methods and paradigms

TC8. Articulating knowledge objects from various areas

These competences were defined in a general way because they can be used in a specific context, related with a professional area of practice and an IEM domain of knowledge. For clarifying this concept, it is possible to present some examples:

- TC1, "Production systems analysis and diagnosis" - it is possible, as an example to have specific competences related to the following two domains of knowledge: Simulation - Interpret and analyze the behavior of a real production system; Production Management - Identify the requirements for implementing the processes of Production Management.
- TC2, "Production systems design / Production Planning and Control processes design" example: "Production Systems Design" - Improving the performance of a production system; "Ergonomic Workplace Analysis" - Apply anthropometric data from a population in the design of a workplace.
- TC5, "Developing projects, implementing systems, applying methods and procedures" example: Calculus - Define and calculate the integral of a real function of a real variable in the calculation of areas, volumes, arc lengths and areas of surfaces of revolution.

2.2.2 *Transversal Competences*

Transversal competences (also known as "generic competences", "transferable competences", "core competences", "professional competences") refer to those competences that are beyond technical subjects but are also related to professional practice.

These competences have been quite valued by professional associations, including the ones that are responsible for the accreditation of engineering programs (namely ABET and EUR-ACE). They are also valued by the professionals [27] and by the academia, following the goals of the Bologna Process.

Selecting these kinds of competences is not an easy task because, apparently, all of them seem to be relevant.

Thus, the selection takes into account evidence from the engineering branch considered in this study. In this sense, the framework presents eleven IEM transversal competences (TRC):

TRC1. Communication competences

TRC2. Ability to deal with the unexpected / Working in environments of uncertainty

TRC3. Teamwork competences

TRC4. Ability to solve problems

TRC5. Leadership competences

TRC6. Innovation / Creativity

TRC7. Planning and organization competences

TRC8. Professional ethic

TRC9. Ability to making decisions

TRC10. Foreign languages knowledge

TRC11. Entrepreneurship

An example will be presented in order to show the applicability of these competences in specific contexts. The importance of transversal competences arises from the demands of professional practice. The industrial engineers, for instance, may need to develop a project for improvement of a production system or subsystem of a company in order to solve a problem identified [TRC4] and this implies being able to manage an interdisciplinary project team to introduce the changes in the system [TRC3].

2.3 **Process of Confirmation of the Selected Competences**

Triangulation of data was used to make a confirmation of the representativeness of the set of selected competences, in order to enhance the consistency of the results [28].

A survey was designed in order to analyse the perspectives of the participants about the competences identified during document analysis. This survey was applied to three different stakeholders:

- students' and staff participating at the IEM Integrated Master course (IEM-IM) at the University of Minho, because this is where the case study and the framework is intended to be applied ;
- professionals of this engineering field related with the IEM-IM. Professionals can bring important inputs to define competences needed in the organizations (Perunovic, Christoffersen, &Mefford, 2012) and for that reason they were considered key informants in this study.

The list of competences (both technical and transversal) was presented to the participants and they were asked to indicate their level of agreement with each statement related to its importance for professional practice.

This survey was previously validated by four independent specialists, two from the IEM field and two from the educational field, for semantic and content validation purposes, namely about interpretation of questions, length of the questionnaire, scales and also the relevance of the competences in relation to the professional profile.

The survey was conducted over a period of three months (April to June 2012) through a questionnaire available online.

Participants

- The survey was sent to all students enrolled in 2011/12 IEM-IM program; 269 students in total. 100 completed questionnaires were received, which represents a 37% return rate.
- All staff involved in 2011/12 IEM-IM program and also all staff of the Department of Production and Systems that are involved in the IEM knowledge field courses to other engineering degrees was invited to participate. The survey was sent to 88 teachers and 26 responses were received, representing a return rate of 30%.
- All IEM-IM alumni and also Portuguese professional institution members were also invited to participate. The survey was directly sent to 127 IEMIM professionals graduated from 2007 to 2011. A total number of 49 responses were received, representing a return rate of 39%. The survey was also sent to professionals using indirect procedures, both through the IEM ALUMNI association at the University of Minho (11 responses) and the Portuguese professional association (18 responses). In total, 78 responses from professionals were obtained.

After the design process, based on thorough document analysis and specialists' validation, a high degree of agreement among respondents was expected, as represented in **Table 3** and **Table 4**.

Table 3. Survey results aggregating scales 4 and 5 of higher agreement with the selected technical competences

Answers (%)	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8
Students Average=97	98	96	97	97	96	97	87	97
Staff Average=91	96	96	96	96	92	96	92	96
Professionals Average=98	100	95	97	96	95	96	71	99

Regarding the technical competences, the lower degree of agreement (71%) came from professionals in relation to the TC7 – "Describing, comparing and selecting technologies, methods and paradigms", which is the competence more intrinsically related to knowledge domain. This was consistently considered to be the competence less relevant with degrees of agreement of 87% from the students and 92% from staff.
Staff responses represent a small variation from 92% to 96% which represents a high degree of agreement to the framework. Despite this general agreement, the most relevant competence identified by both professionals and students was TC1 – "Production systems analysis and diagnosis". A high degree of agreement from professionals was also obtained for TC8 – "Articulating knowledge objects from various areas".
Regarding the transversal competences, there is also a high degree of agreement (**Table 4**). The average degree of agreement of staff regarding the transversal competences is 91%. This value is lower than the ones from students (97%) and from professionals (98%).

The lowest degree of agreement from professionals and the second lowest from staff is TRC6 – "Innovation / Creativity". The lowestdegree of agreement considering the perceptions of staff is TRC5 – "Leadership competences". The lowest degree of agreement, considering the perceptions of students is TRC1 – "Communication competences" and TRC8 – "Professional ethic".
Both students and professionals identify a set of transversal competences with high level of agreement: TRC3 – "Teamwork competences"; TRC4 – "Ability to solve problems"; TRC7 – "Planning and organization competences"; TRC9 – "Ability to making decisions". Furthermore, professionals agree with TRC10 – "Foreign languages knowledge". The perceptions from students and professionals are therefore quite aligned.

Table 4. Survey results aggregating scales 4 and 5 of higher agreement with the selected transversal competences

Answers	TRC										
(%)	1	2	3	4	5	6	7	8	9	10	11
Students Average=97	91	98	100	100	96	96	100	91	100	97	99
Staff Average=91	93	92	92	92	85	88	92	92	92	92	92
Professionals Average=98	97	99	100	100	96	90	100	96	100	100	96

3. APPLICATION OF THE FRAMEWORK IN IEM CURRICULUM

The usefulness of the framework is to be a tool for curriculum design, analysis and review, including the teaching and learning processes and the alignment of the curriculum with the professional profile. In this sense, the application of the framework was made in IEM-IM program using the learning outcomes because the curriculum organization in European Higher Education institutions is mostly based on learning outcomes. The aim is to promote students' mobility, academic degrees comparability in European Higher Education Area and a shift to student-centered learning process [29]. Learning outcomes are "statements of what a learner is expected to know, understand and/or be able to demonstrate after a completion of a process of learning" [30]. In this sense, learning outcomes are related to the requirements to achieve credits (ECTS – *European Credit and Transfer System*) in a course unit or module [31].
The IEM-IM curriculum is adapted to the Bologna Process principles since 2006/2007, with a structure based on two integrated cycles of 5 years (Master), corresponding to 300 ECTS. Additionally, there is a strong investment on active learning methodologies, particularly Project-Based Learning [32-34]. The aim of IEM-IM program is to train engineers with technical and scientific knowledge capable to guarantee a competitive performance of production systems of different industrial companies (http://miegi.dps.uminho.pt – degree program site in Portuguese).

For this study the full set of the 2011/12 courses (60) were analysed, which include 298 learning outcomes. As for the elective courses, only the ones in operation during this academic year were considered. In short, 298 learning outcomes were classified in relation to the framework of competences. First an analysis of all the courses and respective learning outcomes (LO) as a means of identifying the competences was done. Then a cross-analysis in each of the IEM knowledge areas was developed, creating a two-dimensional perspective of the intensity of the competences developed by knowledge area.

3.1 Learning Outcomes analysis

The result of the analysis of LOs showed that the formal definition of most courses has a much stronger focus on the technical aspects than transversal ones in the formal curriculum.

Considering the 298 LO referred in the 60 courses in operation in 2011/12, a cross-identification was done with 8 technical competences, which resulted in a total number of 431 identified cross-references (**Figure 2**).

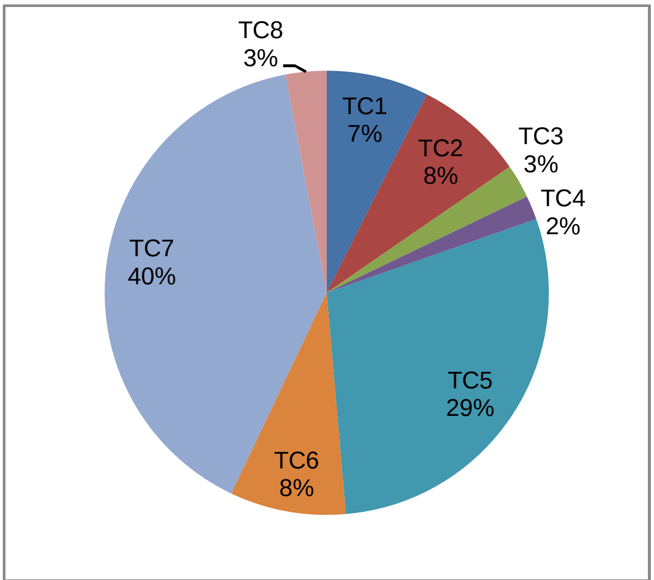

Figure 2. Technical competences analysis(see section 2.2.1for a comprehensive list of TCs)

Regarding the technical aspects, the recurrent elements relate to the domain of knowledge, together with its implementation, in opposition to the design dimension and interdisciplinary. Despite that, considering the survey, this competency was consistently considered to be as the least relevant by the participants.

Regarding the transversal competences represented in Figure 3, and considering the same 298 LOs, there were only 28 identified cross-references. From these 28, half (14) are identified in the two formal project-based learning courses included in the curriculum.

The analysis stressed that there is a strong focus on "Communication competences" and "Ability to solve problems."

There are two types of competences that are not mentioned in the courses: "Foreign languages knowledge" and "Entrepreneurship". However "Entrepreneurship" is present in some elective courses that were not in operation in this academic year. This is also present in an elective project involving 8 of the 45 students enrolled in the 4th year of the course in 2011/12.

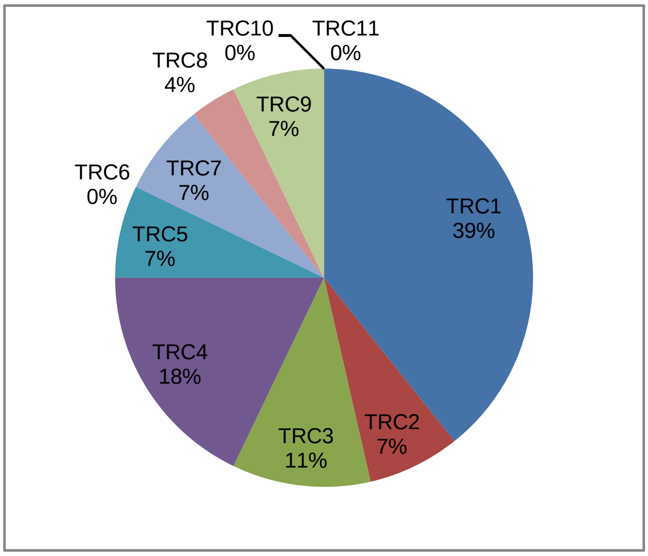

Figure 3. Transversal competences analysis (see section 2.2.2 for a comprehensive list of TRCs)

3.2 Relation between Learning Outcomes and Knowledge Areas

In order to do a more comprehensive and integrated analysis of the curriculum it is important to look at it from different dimensions. In particular, it is possible to create a view representing the intensity of the development of competences in each knowledge area. From the point of view of the formal curriculum, this can be done by comparing planned written learning outcomes for each course and then aggregating them by knowledge area. In this study a double perspective regarding the IEM knowledge areas are used: aggregated areas and specific IEM areas.

This classification of areas of knowledge has been first presented in Lima, et al. [17]. Two specific areas have generic descriptive names: “IEM – Project” and “IEM – IEM”. The former represents courses specifically dedicated to project work, namely Project-Based Learning methodology with a strong emphasis on interdisciplinarity and teamwork. The latter refers to courses that are so vast in their learning objectives that must be classified as belonging to the area as a whole. This is the case of Introduction to IEM and master dissertation courses.

Table 5. presents the relationship between learning outcomes and knowledge areas, both aggregated and specific. This table also shows the weight of knowledge areas in ECTS column. It is evident that IEM aggregated area is the most important in the curriculum corresponding to almost 60% of the total amount of work in the program.Regarding the aggregated results, a similar set of results are represented in **Table** when comparing to prior section, because both data was

based on LO from all courses. Nevertheless, this table adds a new relational perspective between competences and each area of knowledge.

Analyzing the aggregated area of the table (top of the table), excluding IEM specific areas, neither "Basic Sciences", nor "Economics and Management" or "Engineering Sciences" relate to TC3 – "Planning production and project processes", TC4 – "Monitoring and Controlling processes and production system performance" and TC8 – "Articulating knowledge objects from various areas". Regarding TC3 and TC4, they are rather specific to IEM profile. But TC8 is the competency related to the articulation among areas of knowledge and is identified in other areas of engineering curricula. This analysis gives some good indications that other areas are formally seen and defined as islands of knowledge that engineers should acquire, and their significance for the professional profile is not explored, at least in the formal curriculum. Furthermore, these areas do not emphasis transversal competences.

The IEM specific areas have some "strong" (regarding ECTS totals) areas: "Production Management", "Ergonomics and Human Factors", "Operations Research" and "Quality". Further, "IEM – IEM" that includes the master dissertation is the area with the large weight in the curriculum.

The technical competency with the higher degree of agreement among professionals, regarding the importance for professional profile, is TC1 – "Production systems analysis and diagnosis". Analyzing the results represented in the formal curriculum it can be argued this competency has been ranked 5 in 8 regarding the ECTS weight and this is fundamentally concentrated in 4 areas of knowledge.

4. FINAL REMARKS

This paper presents a framework of competences developed for Industrial Engineering and Management. It involved a meticulous methodological process based on literature review, document analysis and a survey. The application of the framework in the IEM program at University of Minho shows that it can be used as a tool for curriculum design, analysis and review, including the teaching and learning processes and the alignment of the curriculum with the professional profile. The learning outcomes (defined by the teachers) should reflect students' developing competences [35] which should be linked to the professional practice. The results of the application of the framework corroborate other studies which reinforce the need to review the IEM curriculum considering the professional practice [36]. The most visible aspect in the learning outcomes of IEM program is the lack of balance between technical and transversal competences. There was not almost any reference to the transversal competences and it is fundamentally concentrated on Project-Based Learning courses. Despite the importance of transversal competences for the professional profile which is evident from the survey analysis, the development of transversal competences is identified in a number of areas of knowledge, and fundamentally attached to project courses. This suggests that some issues need to be reviewed in the curriculum and for that teachers, students and even professionals need to be involved. According to Stefani [37], this approach is essential for planning teaching and learning processes: "(…) we can provide transparency for our students regarding the intended learning outcomes for any course or program, and the more clear we can be in aligning our assessment strategies and processes with the intended learning outcomes". It is also relevant the impact of PBL in the curriculum, because it promotes teaching and learning, namely in competences' development that are aligned to professional profile [38-42]. The literature highlights the importance to invest in this learning approach, and specifically Brandon-Jones, et al. [43] draw attention to the importance to have graduates with competences related to their professional practice.

The application of the framework confirms that it may be a tool to analyse the curriculum. In addition, it is also useful for staff at Higher Education, particularly in engineering field without pedagogical training. In this sense, this approach could help them think about their teaching practice and to improve it, aligning the competences reflected in the learning outcomes with the competences expected in professional practice. The framework might also be useful for planning purposes using different approaches. The framework may also contribute to better understand Industrial Engineering and Management as a specific field as it involving different perspectives drawing from several studies, professional associations, amongst other sources, which were integrated in the framework to get a common vision.

The framework was implemented in a single case (IEM program at University of Minho). It thus needs to be used in other settings in order to explore further its consistency and validity.. In fact, the framework has potential to be applied in other contexts considering the adequate information, such as learning outcomes or other formal documents from the curriculum. The benefit of framework is its flexibility that enables its use in any context related to Industrial Engineering and Management in order to foster the connection between the curriculum design, professional profile and competences development.

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5. REFERENCES

[1] European_Commission. (2008, 03/01/2013). New skills for new jobs: better matching and anticipating labour market needs. Available: http://ec.europa.eu/education/news/news1110_en.htm

[2] CEDEFOP, "Skill mismatch: the role of the enterprise," Publications Office of the European Union, Thessaloniki, Greece 978-92-896-0918-0, 2012.

[3] S. Hennemann and I. Liefner, "Employability of German Geography Graduates: The Mismatch between Knowledge Acquired and Competences Required," *Journal of Geography in Higher Education,* vol. 34, pp. 215-230, 2010/05/01 2010.

[4] A. Marie-Emmanuelle, B. Michèle, P. Véronique, F. Jean, and I. Ion, "Student's Quality of Life and Employability Skills: SQALES a device and a tool for universities. Example of use in Luxembourg, Belgium and Romania - Student's Quality of Life and Employability Skills," *Revista de cercetare si interventie sociala,* vol. 28, pp. 97-114, 2010.

[5] R. Biesma, M. Pavlova, R. Vaatstra, G. Merode, K. Czabanowska, T. Smith, and W. Groot, "Generic Versus Specific Competencies of Entry-Level Public Health Graduates: Employers' Perceptions in Poland, the UK, and the Netherlands," *Advances in Health Sciences Education,* vol. 13, pp. 325-343, 2008/08/01 2008.

[6] C. M. V. D. Heijde and B. I. J. M. Van Der Heijden, "A competence-based and multidimensional operationalization and measurement of employability," *Human Resource Management,* vol. 45, pp. 449-476, 2006.

[7] H. Schaeper, "Development of competencies and teaching–learning arrangements in higher education: findings from Germany," *Studies in Higher Education,* vol. 34, pp. 677-697, 2009/09/01 2009.

[8] A. Gonczi, "The OECD: Its Role in the Key Competencies Debate and in the Promotion of Lifelong Learning," in *Graduate Attributes, Learning and Employability*. vol. 6, P. Hager and S. Holland, Eds., ed: Springer Netherlands, 2006, pp. 105-124.

[9] IIE-Ireland. (2012, 2012.12.08). *Industrial Engineering Standards in Europe (IESE)* [Digital pdf Report]. Available: http://www.iieireland.net/#/iese-report/4570401227

[10] J. A. Marin-Garcia, J. P. Garcia-Sabater, C. Miralles, and A. R. Villalobos, "Profile and competences of Spanish industrial engineers in the European Higher Education Area (EHEA)," *Journal of Industrial Engineering and Management* vol. 1, pp. 269-284, 2008.

[11] H. Eskandari, S. Sala-Diakanda, S. Furterer, L. Rabelo, L. Crumpton-Young, and K. Williams, "Enhancing the undergraduate industrial engineering curriculum: Defining desired characteristics and emerging topics," *Education and Training,* vol. 49, pp. 45-55, 2007.

[12] C. Basnet, "Production management in New Zealand: Is education relevant to practice?," *International Journal of Operations and Production Management,* vol. 20, pp. 730-745, 2000.

[13] UNESCO. (2010, Engineering: Issues, Challenges and Opportunities for Development. Available: http://unesdoc.unesco.org/images/0018/001897/189753e.pdf

[14] APICS, *APICS Operations Management Body of Knowledge Framework (OMBOK)*, 2nd ed. Chicago: APICS, 2009.

[15] IIE. (2012). *Institute of Industrial Engineers (IIE): About IIE*. Available: http://www.iienet2.org/Details.aspx?id=282

[16] L. Martin-Vega, "The Purpose and Evolution of Industrial Engineering," in *Maynard's Industrial Engineering Handbook*, K. B. Zandin, Ed., 5th ed New York: McGraw Hill, 2001, pp. 1.3 - 1.19.

[17] R. M. Lima, D. Mesquita, M. Amorim, G. Jonker, and M. A. Flores, "An Analysis of Knowledge Areas in Industrial Engineering and Management Curriculum," *International Journal of Industrial Engineering and Management,* vol. 3, pp. 75-82, 2012.

[18] C. Billings, J. J. Junguzza, D. F. Poirier, and S. Saeed, "The Role and Career of the Industrial. Engineer in the Modern Organization," in *Maynard's Industrial Engineering Handbook*, K. B. Zandin, Ed., 5th ed New York: McGraw Hill, 2001, pp. 1.20-.

[19] G. Le Boterf, *Construir as competências individuais e coletivas. Resposta a 80 questões.* Porto: Edições Asa., 2005.

[20] G. Le Boterf, *De la compétence à la navigation professiionelle.* Paris: Éditions d' Organisation, 1997.

[21] P. Perrenoud, "De uma metáfora a outra: transferir ou mobilizar conhecimentos?," in *O enigma da competência em educação*, J. Dolz and E. Ollagnier, Eds., ed Porto Alegre: Artmed, 2004, pp. 47-63.

[22] G. Le Boterf, *L' ingénierie et évalution des competences*. Paris: Les Éditions d' Organisation, 2004.

[23] A. Stoof, R. L. Martens, J. J. G. van Merriënboer, and T. J. Bastiaens, "The Boundary Approach of Competence: A Constructivist Aid for Understanding and Using the Concept of Competence," *Human Resource Development Review,* vol. 1, pp. 345-365, September 1, 2002 2002.

[24] G. P. Bunk, "La transmisión de las competencias en la formación y perfeccionamiento profesionales de la RFA," *Revista Europea de Formación Profesional,* vol. 0258-7483, pp. 8-14, 1994.

[25] L. Mertens, *Competencia laboral: sistemas, surgimiento y modelos*. Montevideo: Cinterfor, 1996.

[26] Tuning. (2007, 2013.03.01). *Tuning Project Report : General Brochure final version*. Available: http://www.unideusto.org/tuningeu/images/stories/documents/General_Brochure_final_version.pdf

[27] R. M. Lima, D. Mesquita, and C. Rocha, "Professionals' Demands for Production Engineering: Analysing Areas of Professional Practice and Transversal Competences," in *International Conference on Production Research (ICPR 22)*, Foz do Iguassu, Brazil. , 2013.

[28] N. K. Denzin, Ed., *Sociological Methods: A Sourcebook (Methodological Perspectives)* Transaction Publishers, 2006, p.^pp. Pages.

[29] Bologna_Declaration_CRE. (1999, 2013.03.01). *The Bologna Declaration on the European space for higher education: an explanation*. Available: http://ec.europa.eu/education/policies/educ/bologna/bologna.pdf

[30] CEDEFOP, "The shift to learning outcomes. Policies and Practices in Europe," Office for Official Publications of the European Communities, Thessaloniki, Greece 978-92-896-0576-2, 2009.

[31] ECTS-EC. (2004, 2012.05.22). European credit transfer and accumulation system (ECTS) - Key features. Available: http://ec.europa.eu/dgs/education_culture/publ/pdf/ects/en.pdf

[32] R. M. Lima, E. P. Cardoso, G. Pereira, S. Fernandes, and M. A. Flores, "Aprendizagem Baseada em Projectos Interdisciplinares num Curso de Engenharia: uma Leitura dos Resultados Académicos," *Revista Galego-Portuguesa de Psicologia e Educação (Número Especial relativo ao IX Congresso Galaico-Português de Psicopedagogia - Eds. Barca, A., Peralbo, M., Porto, A., Duarte da Silva, B. e Almeida, L.),* pp. 1269-1280, 2007.

[33] S. Fernandes, M. A. Flores, and R. M. Lima, "Student's views of assessment in project-led engineering education: findings from a case study in Portugal," *Assessment & Evaluation in Higher Education,* vol. 37, pp. 163-178, 2012.

[34] R. M. Lima, D. Carvalho, R. M. Sousa, A. Alves, F. Moreira, D. Mesquita, and S. Fernandes, "A Project Management Framework for Planning and Executing Interdisciplinary Learning Projects In Engineering Education," in *Project Approaches to Learning in Engineering Education: The Practice of Teamwork*, L. C. d. Campos, E. A. T. Dirani, A. L. Manrique, and N. v. Hattum-Janssen, Eds., ed Rotterdam, The Netherlands: SENSE, 2012, pp. 53-76.

[35] J. Bingham, *Guide to Developing Learning Outcomes*. Sheffield: Sheffield Hallam Institute, 1999.

[36] J. A. Marin-Garcia, J. P. Garcia-Sabater, M. R. Perello-Marin, and L. Canos-Daros, "Propuesta de competencias para el Ingeniero de Organización en el contexto de los nuevos planes de estudio," *Intangible Capital,* vol. 5, pp. 387-406, 2009.

[37] L. Stefani, "Planing Teaching and Learning: Curriculum design and development," in *A Handbook for Teaching and Learning in Higher Education. Enhancing Academic Practice*, Fry, Ketteridge, and Marshall, Eds., 3rd ed London: Routledge, 2009, pp. 40-57.

[38] L. Helle, P. Tynjälä, and E. Olkinuora, "Project-based learning in post-secondary education - theory, practice and rubber sling shots," *Higher Education,* vol. 51, pp. 287-314, 2006.

[39] M. Prince and R. Felder, "Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases," *Journal of Engineering Education,* vol. 95, pp. 123-138, 2006.

[40] J. Mills and D. Treagust. (2003, Engineering education – is problem-based or project-based the answer? *Australasian Journal of Engineering Education*. Available: http://www.aaee.com.au/journal/2003/mills_treagust03.pdf

[41] T. Litzinger, L. Lattuca, R. Hadgraft, and W. Newstetter, "Engineering Education and the Development of Expertise," *Journal of Engineering Education,* vol. 100, pp. 123–150, 2011.

[42] M. Jollands, L. Jolly, and T. Molyneaux, "Project-based learning as a contributing factor to graduates' work readiness," *European Journal of Engineering Education,* vol. 37, pp. 143-154, 2012.

[43] A. Brandon-Jones, N. Piercy, and N. Slack, "Bringing teaching to life: Exploring innovative approaches to operations management education," *International Journal of Operations and Production Management,* vol. 32, pp. 1369-1374, 2012.

Nastavni plan za industrijsko inženjerstvo i menadžment: razvijanje okvira veština i znanja

Diana Mesquita, Rui M. Lima, Maria A. Flores, Claisy Marinho-Araujo, Mauro Rabelo

Primljen (14.01.2015); Recenziran (26.08.2015); Prihvaćen (14.09.2015)

Rezime

Rad predstavlja okvir veština i znanja za industrijsko inženjerstvo i menadžment koji može da se koristi kao alat za analizu i planiranje nastavnog plana, uključujući procese podučavanja i učenja, kao i za usaglašavanje nastavnog plana sa profesionalnim profilom. Okvir je primenjen na programu industrijskog inženjerstva i menadžmenta na Univerzitetu Minho, Portugalija, i pruža pregled povezanosti između znanja u oblasti industrijskog inženjerstva i menadžmenta (IIM) i kompetencija definisanih u nastavnom planu. Okvir veština i znanja je razvijen unutar procesa analize korišćenjem kombinacije metoda i izvora za sakupljanje podataka. Okvir je razvijen u skladu sa četiri glavna koraka: 1) karakterizacija IIM znanja; 2) definisanje veština i znanja za IIM; 3) upitnik; i 4) primena okvira na IIM nastavni plan. Rezultati su pokazali da je okvir koristan za izgradnju integrisane vizije nastavnog plana. Najvidljiviji aspekt rezultata učenja IIM programa je nedostatak ravnoteže između tehničkih i transverzalnih kompetencija. Ranije, gotovo da nije postojala ni jedna referenca o transverzalnim kompetencijama i program je u osnovi bio koncentrisan na kurseve učenja na osnovu projekata. Okvir koji je predstavljen u ovom radu pruža doprinos definisanju IIM profesionalnog profila putem niza kompetencija koje treba dalje da se istraže. Pored toga, to može da bude značajan alat za analizu nastavnog plana za IIM i doprinos za premošćavanje prostora između univerziteta i kompanija.

Ključne reči: *Industrijsko inženjerstvo i menadžment (IIM), kompetencije, IIM polja znanja, analiza nastavnog plana*

Table 5. Relationship between LO and Knowledge Areas

Aggregated classification	**ECTS**	**TC1**	**TC2**	**TC3**	**TC4**	**TC5**	**TC6**	**TC7**	**TC8**	**TRC1**	**TRC2**	**TRC3**	**TRC4**	**TRC5**	**TRC6**	**TRC7**	**TRC8**	**TRC9**	**TRC10**	**TRC11**
Basic Sciences	49	1				36	3	42		1										
Economics and Management	19,5	4	1			6	3	14		1			1				1			
Engineering Sciences	55	5	8			20	3	39												
Industrial Engineering and Management	176,5	20	23	10	7	55	25	66	12	9	2	3	4	2	0	2	0	2	0	0
Grand Total	**300**	**30**	**32**	**10**	**7**	**117**	**34**	**161**	**12**	**11**	**2**	**3**	**5**	**2**		**2**	**1**	**2**		
Industrial Engineering and Management**specific classification**	**ECTS**	**TC1**	**TC2**	**TC3**	**TC4**	**TC5**	**TC6**	**TC7**	**TC8**	**TRC1**	**TRC2**	**TRC3**	**TRC4**	**TRC5**	**TRC6**	**TRC7**	**TRC8**	**TRC9**	**TRC10**	**TRC11**
IEM – Automation	7,5		3			3	3	6												
IEM - Computer and Information Systems	5	1				2	1	2												
IEM - Economics Engineering	5		1		1	2														
IEM - Ergonomics and Human Factors	17,5	2	3	1		8	4	9												
IEM – Logistics	5	1		1		2		2	2											
IEM – Maintenance	5	3	1	1		3		2												
IEM - Operations Research	18	3	3			6	3	5												
IEM - Product Design	5		1			3		1	1											
IEM - Production Management	27,5	4	3	3	2	9	6	15	3	4										
IEM – Project	10		2	2	2	4	2		2	2	2	2	2	2		2		2		
IEM - Project Management	10	3	1	1	1	4	2	5	1	2		1								
IEM – Quality	12,5	1	1			6	3	10	1											
IEM – Simulation	5	1	1			1	1													
IEM – Sustainability	2,5	1	1					2												
IEM – IEM	41		2	1	1	2		7	2	1			2							
Grand Total	**176,5**	**20**	**23**	**10**	**7**	**55**	**25**	**66**	**12**	**9**	**2**	**3**	**4**	**2**	**0**	**2**	**0**	**2**	**0**	**0**
		8,3%	**9,5%**	**4,1%**	**2,9%**	**22,7%**	**10,3%**	**27,3%**	**5,0%**	**3,7%**	**0,8%**	**1,2%**	**1,7%**	**0,8%**	**0,0%**	**0,8%**	**0,0%**	**0,8%**	**0,0%**	**0,0%**