Curriculum Analysis Process: analysing fourteen Industrial Engineering programs

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Abstract

The fourth industrial revolution is demanding for new competences, thus requiring curricula redesign. A comprehensive analysis of current curricula contributes for the design of the new foreseen curricula. According to Hoffman (1999, p. 283): "the design of learning programs may be based on the inputs needed or the outputs demanded". Thus, curriculum analysis is helpful to identify aspects that are working and those that need a change (Wolf, Hill, & Evers, 2006). This purpose is crucial in the context of Industry 4.0, in order to prepare future engineers to face the challenges of their practice. Considering that in Europe, in general, formal curriculum level presents the structural aspects (e.g. hours and number of courses) and the learning outcomes of each course, it is possible to identify the areas of knowledge and the competences students are expected to develop. This paper aims to make a curriculum analysis, based on areas of knowledge and learning outcomes. This was based on a process exploring information from the formal level of curriculum that can be replicated in other contexts. Additionally, the process was applied to fourteen European Industrial Engineering master programs. The results show that there is a high level of diversity regarding main areas of knowledge and technical competences of each program. Moreover, it showed an enormous lack of attention in terms of transversal competences in all programs.

Keywords: Active Learning; Project-Based Learning; Engineering Education; Curriculum Design; Curriculum Analysis

1 Introduction

According to Hoffman (1999, p. 283): "the design of learning programs may be based on the inputs needed or the outputs demanded". Thus, curriculum analysis is helpful to identify aspects that are working and those that need a change (Wolf, Hill & Evers, 2006). This purpose is crucial in the context of Industry 4.0, in order to prepare future engineers to face the challenges of their practice. In fact, the professional practice requires the combination of different competences and, for that reason, they must be included in the curriculum. However, the curriculum and the pedagogical practice are not always aligned with this purpose (Jackson, 2012; Markes, 2006; Nair, Patil, & Mertova, 2009; Stiwne & Jungert, 2010; Tymon, 2013). In short, for an understanding about the curriculum it is essential to understand it as a project that includes (i) the teaching and learning experiences, (ii) the process of its development - design, development and evaluation - and (iii) the following key elements - objectives, content, resources, assessment, and teaching and learning strategies (Barnett & Coate, 2005; Biggs, 1996; Zabalza, 2009). With this in mind, two important issues should be addressed, considering the scope of this work: planning and curriculum levels.

Planning the curriculum as a project involves thinking about the activities that will be developed, the strategies to present the contents to students, the learning outcomes that should be defined, amongst others questions. Issues such as methods: contents; the organization of learning environment to interact with students; student support (e.g. tutorials); learning support material (e.g. guides); teachers' coordination and cooperation; and the evaluation must be also considered. These elements cannot be defined separated from each other (Barnett & Coate, 2005; Cowan, 2006; Kirkpatrick & Kirkpatrick, 2005; Mesquita, 2015; Wolf, 2007; Zabalza, 2009). All of them should be aligned (Biggs, 1996), in order to create meaningful teaching and learning experiences.

Analysing the curriculum implies identifying and defining it at different levels (Goodlad, 1979). The Ideal Curriculum refers to the rational of basic philosophy underlying a curriculum, it represents ideas on believes and intentions. All possibilities are allowed, because it is all about the ideas. The Formal Curriculum is a transformation of the ideal curriculum in formal documents. Can be developed at different contexts: Ministry of Education (macro), University (meso), and Teacher (micro). The Operational Curriculum refers to what actually happens in the classroom. This is related to the teaching and learning practices and the interaction between teachers, students and, in some occasions, other stakeholders (e.g. companies' representatives).

The term Industrial Engineering (IE) is most of the times referred with a meaning that can be seen as being mostly equivalent or overlapped with some other terms, e.g. Industrial Engineering and Management, Engineering Management, Engineering Systems, Production Engineering, and Manufacturing Engineering. This is can be caused by the diversity of the field itself and by the close relation it has with all other engineering fields. Industrial Engineering can be defined 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 (IISE, 2017; Lima, Mesquita, Rocha, & Rabelo, 2017). Thus, as can be inferred by this definition, IE can be seen as the field related to designing, organizing and managing processes related to production of products and services, being this products and services designed and produced / executed under the concepts of other engineering fields.

The diversity within the IE field reflects on the curriculum organization, which implies an interdisciplinary approach, bringing together the different areas of knowledge that IE integrates. The context of Industry 4.0 is challenging the industries for change, connecting technologies together, and for that reason, preparing industrial engineers for these challenges is mandatory. It is an opportunity to re-think curricula, pedagogical practices and the competences that students need to develop to be prepared for this challenging environment. This is the main objective of a European project consortium involving three European universities, from Poland, Portugal and Romania, and six Thai universities (http://ise-portal.ait.ac.th/). In this context, this work aims to provide a comprehensive analysis of existing IE Master curricula, contributing for the design of the new foreseen curricula. The output of this work may contribute for creating a methodology for curriculum analysis and to an understanding about the IE curricula in European countries. This understanding may create a ground base for the identification of existing gaps between competences' needs for Industry 4.0 and the academic development of Industrial Engineering master students.

2 Methodological approach

In the scope of this work, the diversity of institutions and programs to be analysed implies a definition of multiple sources and methods, as recommended by Wolf et al. (2006). With this in mind, and focusing on formal level of the curriculum (Goodlad, 1979), several types of information may be analysed in order to identify specific curricula elements, mainly concerning to the structure of the different programs, type of educational experiences, areas of specialization and objectives / learning outcomes. These elements are essential to analyse the IE competences in the context of Industry 4.0. This paper will focus on collecting different information regarding formal curriculum (documents related to the master program). An Excel template was developed and filled by different partners to collect information about curriculum structure, areas of specialization and learning outcomes. Figure presents a schematic representation of the method followed during the execution and analysis phases.

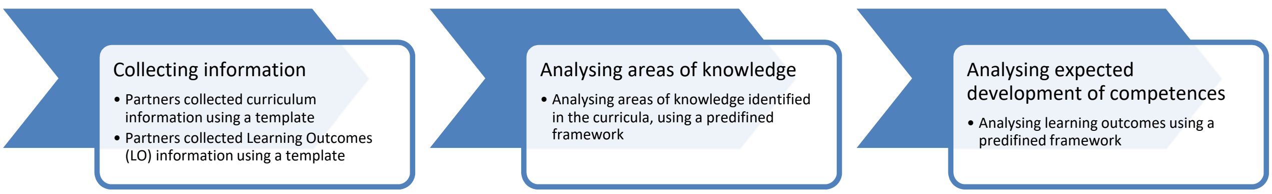

Figure 1. Execution and analysis phases of Task 1.2 methodology

Reviewing IE curricula is based on data collected from partners. First, information is collected from the courses, class types, hours of contact and credits. In a second form, information is gathered from learning outcomes in order to identify the expected competences to be developed by the graduates. The programs were selected for analysis based on two main criteria, being related to the HEI enrolled in the previously referred European project, and being from other HEI selected by convenience of accessing the required data.

2.1 Framework for analysis

Considering that courses mainly involve 1 or 2 main fields of knowledge, their title, objectives and short descriptions allow to identify the main areas of knowledge (AK) of each course, and consequently of each program. Additionally, as learning outcomes (LO) can be seen as "statements of what a learner is expected to know, understand and / or be able to demonstrate after a completion of a process of learning" (CEDEFOP, 2009), that makes possible to identify the expected competences that students should be able to develop with those courses. Aggregating this information will allow to create a map of competences (LO) that are being considered in the context of the different programs.

Regarding the IE areas of knowledge (AK) analysis, a framework of analysis was developed. This framework used as a baseline some previous works (Lima, Mesquita, Amorim, Jonker, & Flores, 2012; Lima et al., 2017), which defied Areas of Knowledge based on a thorough analysis of literature and professional associations. The final list of areas of knowledge were updated considering additional areas (marked with *), which were necessary for the classification of several courses. The final list follows: AK1 Automation; AK2 Computer and Information Systems (*); AK3 Economics Engineering; AK4 Ergonomics and Human Factors; AK5 Industrial Engineering and Management; AK6 Industrial Optimization; AK7 Innovation and Entrepreneurship (*); AK8 Maintenance; AK9 Marketing; AK10 Product Design; AK11 Production Management; AK12 Project Management; AK13 Quality; AK14 Research Methods (*); AK15 Sociology and Law (*); AK16 Supply Chain Management; AK17 Sustainability (*); AK18 Systems Design (*); AK19 Other (*). Two broad categories deserve a special explanation: (i) "Industrial Engineering" implies an interdisciplinary approach, in which several elements of IE, from distinct areas, are included in the same context; usually this category should be used for classification of interdisciplinary projects, dissertations, internships and other similar curricular approaches, and, (ii) "Other" refers to other areas that can be identified in the courses but are not commonly included in IE programs. An example could be a course of "English for Industry".

Regarding to the competences identified from learning outcomes, a framework of competences for Industrial Engineering was considered based on Mesquita, Lima, Flores, Marinho-Araujo, and Rabelo (2015). The framework includes a total of 8 technical competences (TC) and a total of 11 transversal competences (TRC). The technical competences, also known as core competences (Yorke, 2004) or subject specific competences, are related to a specific area of knowledge (expertise). The transversal competences, also known as transferable (Yorke, 2004), general (Mertens, 1996), generic or soft skills (Ramesh, 2010), are relevant in several areas of knowledge and professional activity. The list follows: 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; 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;

2.2 Data collection summary

Table summarizes the data gathered from 14 programs of Industrial Engineering, or related, that were selected from European countries. Five of these programs (from 2 countries) do not define LO for each course and for that reason they were not considered in the analysis of competences / learning outcomes. Two programs from Poland were analysed: CUT - Częstochowa University of Technology and AGH - University of Science and Technology. The results from the Portuguese context includes 5 programs, in which 3 are from University of Minho (UMinho_IEM; UMinho_IE; UMinho_ES), 1 from University of Porto (UPorto_IEM) and other from University of Aveiro (UAveiro_IEM). Three of the programs are from UPB - University Politehnica of Bucharest and another from UGhAIasi – "Gheorghe Asachi" Technical University of Iasi. Finally, other programs from EU countries were also considered in the analysis, particularly from IPG - Institut Polytechnique de Grenoble – INP; UG - University of Greenwich; and UPM - Technical University of Madrid.

Table 1. Summary of the European IE programs' curricula analysed

Country - University	Programs	Programs with areas of knowledge	Programs with courses' LO
Portugal – UMinho	3	3	3
Portugal – UPorto	1	1	1
Portugal – UAveiro	1	1	1
Poland – CUT	1	1	1
Poland – AGH	1	1	1
France – IPG	1	1	1
Romania – UPB	3	3	-
Romania – UGhAlasi	1	1	-
Madrid – UPM	1	1	-
UK – UG	1	1	1
	14	**14**	**9**

2.3 Higher Education in Europe - a contextualised brief perspective

For a better understanding about the curriculum analysis, a short overview of European Higher Education contexts must be addressed, specifically regarding to master curriculum principles, structure and organization. The European Higher Education system usually follows the principles of the Bologna Process (Bologna_Declaration_CRE, 1999), focusing on:

- Three cycle system, composed of bachelor (3 years or 4 years), master (2 years or one and half year) and doctorate (3/4 years);
- A standard *European Credit Transfer and Accumulation System* (ECTS), which contribute to enhance the recognition of qualifications and periods of study;
- Strengthened quality assurance, in order to provide students with the knowledge, skills and core transferable competences they need to succeed after graduation.

Different European countries have different approaches to these principles, and a brief analysis of three countries with different approaches will be presented: Poland, Portugal and Romania. Poland has a higher education structure for engineering programs of 3.5 years bachelor (Engineer at Poland) followed by a 1.5 year master of 90 ECTS. Romania has a 4-year bachelor followed by 2 years of master (4+2 model), 240 + 120 ECTS. Finally, Portugal has a structure of 3 years of bachelor (180 CTS) followed by 2 years of master (120 ECTS), i.e. a model of 3+2. It is important to refer the organization of the master programs regarding to ECTS, course units, typology and hours. The general principles are:

- The total estimated workload of a full-time student is 42 hours/week;
- It is expected that the students will have no more than 20 hours of classes in contact with teachers, being the remaining time dedicated to autonomous study work;
- One academic year has 40 weeks and 1 semester has 20 weeks, including 2 to 4 weeks for assessment;
- 1 ECTS credit is worth 28 hours of student workload;
- Each course unit has the total student estimated workload clearly identified and the breakdown is also provided according to the different categorisations. As an example, at University of Minho the following is applied: **T:** Theoretical Lectures; **TP:** Theoretical-practical Lectures; **PL:** Laboratory Classes; **TC:** Supervised Field Work; **S:** Seminars; **OT:** Tutorials; **E:** Placements; **TO:** Guidance Works; **O:** Other Works; **TI:** Independent Work and Assessment.

In the 3+2 model, the master programs have 120 ECTS, usually, during 2 years, i.e. 4 semesters. In some countries, master programs of 1.5 year and 90 ECTS are also accepted, as in the case of Poland. Each semester can have a different number of courses with different number of ECTS, summing up 30 ECTS per semester. As an example, in the specific case of the Master years of the Industrial Engineering and Management Integrated Master (IEM-IM) of University of Minho, each semester is made up of 6 courses with 5 ECTS. The dissertation course is developed approximately during one and a half semester, at the end of second year, and corresponds to 40 ECTS.

3 Analysis of areas of knowledge

This section presents the results related to the analysis of the areas of knowledge (AK). The course title / name / description was crucial to help the research team to identify the AK. The weight of the AK was defined based on: each course individually corresponds to 1 point and the classification focuses on the main AK that the course involves. In some cases, a maximum of 2 AK might be considered. For example, "Supply Chain Optimization" is one course of one of the UMinho programs and was classified with a weight of 0.5 as Industrial Optimization (AK6) and a weight of 0.5 as Supply Chain Management (AK16). Industrial Engineering and Management (AK5) covers several elements of IE representing a significant weight in all programs. Therefore, interdisciplinary projects, dissertations, internships and similar approaches were included here. Under this classification, a sum of the values was computed for each AK of each program, as well as the percentage of each area in each program. The results are provided in Table 2. The first and second columns represent the AK and its code, the next 14 columns refer to the European programs analysed, and, the last 2 columns present the mean and the standard deviation.

Table 2. Areas of knowledge from selected European master programs

Area of Knowledge	AK CODE	AGH_ MPE	CUT_ MPE	UA_ IEM	UM_ IEM	UM_ IE	UM_ ES	UP_ IEM	UGhA Iasi	UPB_ DIPI	UPB_ IE	UPB_ IPFP	IPG	UG	UPM	Mean	STDV
Automation	AK1	0.00	0.00	0.05	0.04	0.00	0.00	0.00	0.07	0.11	0.13	0.10	0.00	0.00	0.13	0.04	0.05
Comp. and Inf. Systems	AK2	0.06	0.09	0.17	0.08	0.07	0.09	0.06	0.03	0.00	0.00	0.03	0.07	0.00	0.04	0.06	0.04
Economics Engineering	AK3	0.06	0.04	0.00	0.00	0.07	0.06	0.06	0.03	0.03	0.00	0.03	0.10	0.20	0.04	0.05	0.05
Ergonomics and Human Factors	AK4	0.01	0.04	0.00	0.05	0.07	0.00	0.00	0.02	0.06	0.00	0.00	0.00	0.00	0.09	0.02	0.03
IEM	AK5	0.04	0.13	0.05	0.15	0.13	0.19	0.13	0.13	0.12	0.25	0.15	0.03	0.21	0.02	0.12	0.07
Industrial Optimization	AK6	0.04	0.09	0.07	0.08	0.11	0.14	0.19	0.05	0.00	0.06	0.00	0.12	0.00	0.00	0.07	0.06
Innovation and Entrepren.	AK7	0.04	0.08	0.16	0.00	0.00	0.02	0.04	0.06	0.06	0.09	0.03	0.03	0.04	0.03	0.05	0.04
Maintenance	AK8	0.00	0.00	0.00	0.05	0.00	0.00	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Marketing	AK9	0.02	0.00	0.05	0.00	0.00	0.04	0.06	0.00	0.00	0.06	0.03	0.01	0.02	0.00	0.02	0.02
Product Design	AK10	0.08	0.04	0.05	0.04	0.05	0.00	0.03	0.03	0.30	0.06	0.18	0.11	0.00	0.12	0.08	0.08
Production Management	AK11	0.24	0.17	0.00	0.25	0.20	0.11	0.06	0.06	0.08	0.06	0.10	0.10	0.11	0.00	0.11	0.08
Project Management	AK12	0.04	0.04	0.00	0.05	0.00	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.07	0.08	0.02	0.03
Quality	AK13	0.00	0.04	0.05	0.10	0.07	0.00	0.04	0.03	0.00	0.00	0.05	0.03	0.07	0.00	0.03	0.03
Research Methods	AK14	0.04	0.04	0.00	0.05	0.07	0.06	0.05	0.06	0.12	0.19	0.15	0.03	0.07	0.00	0.07	0.05
Sociology and Law	AK15	0.16	0.05	0.00	0.05	0.00	0.00	0.06	0.13	0.00	0.03	0.00	0.01	0.03	0.00	0.04	0.05
Supply Chain Management	AK16	0.00	0.00	0.05	0.03	0.07	0.25	0.06	0.00	0.00	0.00	0.00	0.07	0.11	0.03	0.05	0.07
Sustainability	AK17	0.00	0.04	0.15	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.03	0.03	0.05
Systems Design	AK18	0.08	0.09	0.15	0.00	0.04	0.03	0.06	0.15	0.06	0.06	0.03	0.15	0.07	0.34	0.09	0.08
Other	AK19	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.06	0.00	0.10	0.03	0.00	0.04	0.03	0.04

For the Polish case, a specific AK emerge from the results in both programs - Production Management (AK11), with a weight of 17% at CUT and 24% at AGH. Furthermore, at the AGH program, it is also possible to see that Sociology and Law (AK15) related courses have an important role in the curricula (16%), as well as the AK19 "Others", which, in this particular case, are related to "Foreign language (A1 English)" and "Foreign language (B1 English)". The same relevance of Production Management (AK11), previously noticed in the Polish context, can also be found in two Portuguese programs at University of Minho, namely UMinho_IEM (25%) and UMinho_IE (20%). The other UMinho program (UMinho_ES) shows a strong emphasis on Supply Chain Management (AK16) (25%) and Industrial Optimization (AK6) (14%). A similar weight for this AK6 is found in

UPorto_IEM (19%). In the case of the UAveiro_IEM master program, four AK emerge as equally relevant: Computer and Information Systems (AK2) (17%), Innovation and Entrepreneurship (AK7) (16%), Sustainability (AK17) (15%) and Systems Design (AK18) (15%). These results might suggest that a different perspective was adopted in shaping the curricula of this program.

For Romania, one can see that Research Methods (AK14) plays an important role for all programs at UPB (UPB_IE, UPB_DIPI and UPB_IPFP) with a weight of, at least, 12%. This result can be explained by the fact that the courses included in this AK14 are, mainly, related to the final dissertation. In spite of this result, some differences can also be found among these three programs regarding AK. For example, 13% of the UPB_IE curricula focuses on Automation whereas Product Design (AK10) has an important weight in the other two programs (UPB_DIPI 30% and UPB_IPFP 18%). Moreover, both these programs offer courses in Foreign Languages (English and French) that were included in AK19 (Other). Regarding the other Romanian university master program analysed (UGhAIasi), AK18 (Systems Design), AK15 (Sociology and Law) and AK19 (Other) emerge as the most relevant in the curricula, with percentages of 15%, 13%, and 9%, respectively.

A strong focus on AK18 (Systems Design) is also found for IPG (15%) and, particularly, for UPM (34%) master programs. AK10 (Product Design) has a similar weight in both these two programs (11% and 12% for IPG and UPM, respectively). From the analysis of IPG program, one can see that AK6 (Industrial Optimization) (12%) and AK17 (Sustainability) (11%) are also significant AK. As for the case of the UG program, and differently from all the previous programs analysed, AK3 (Economics Engineering) emerges as the most relevant, with a weight of 20%. AK11 (Production Management) and AK16 (Supply Chain Management) are also important having a weight of 11% each.

The last two columns of Table 2 show the mean and standard deviation of the relative weight of each AK for the 14 master's programs analysed. As would be expected from the outset, AK5 (IEM) is the one that represents, on average, the largest relative weight (12%). The second AK that stands out is AK11 (Production Management), with a weight of 11%. Next, the AK of Systems Design (9%), Product Design (8%), Industrial Optimization and Research Methods (7%) and Computing and Information Systems (6%) arise. At the same time, these results also confirm the diversity that encompasses the Industrial Engineering field of study when looking at the values for the standard deviation. This is particularly evident for AK: Automation, Ergonomics and Human Factors, Maintenance, Project Management, Sociology and Law, Supply Chain Management, Sustainability and Other. Therefore, the curricula might vary significantly among different Industrial Engineering master programs, although some AK are a core part of most of the programs analysed.

4 Analysis of learning outcomes

The results related to the development of competences in Industrial Engineering (IE) programs are associated to the learning outcomes (LO) each course aims developing in the students. As explained in the methodology of the study (section 2.1), the learning outcomes of each course have been qualitatively classified based on the predefined framework of technical (TC) and transversal competences (TRC).

As each course usually refer 3 to 6 LO, the classifications of competences are weighted in relation to the number of LO in each course. Thus, for each course, the sum of weights of competences will be up to 1.0. The project participants collected the learning outcomes of IE courses and related programs, mainly in their own universities. Other universities were added to the study in order to create a larger database for analysis. The universities and programs involved were already mentioned in the study about areas of knowledge (section 2.2). Nevertheless, one important issue, that would influence the main recommendations for curriculum design, should be mentioned: several universities, both from Europe and Thailand, do not need to define learning outcomes for their courses. Usually, they define general program objectives, and for the courses, they add some descriptions, topics and objectives, but not a comprehensive set of learning outcomes.

Following the same structure that was used for the areas of knowledge analysis (section 3), the LO analysis was organized in two different sections. The first focuses on Thailand context and the second part focuses on the European context. For the Thai part, only 1 program presented a comprehensive list of learning outcomes useful for the analysis: the AIT program. Regarding the European part, it was possible to collect and analyse information about courses' learning outcomes of 9 programs.

Considering the European project participants, Poland and Portugal define LO for all courses but Romania does not. This is similar to the three additional programs used for the areas of knowledge analysis, from France, UK and Spain; the first two programs define LO for all courses and the third one does not. In summary, this study includes the analysis of 9 IE, or related, master programs learning outcomes.

The integrated perspective of all selected European programs is presented in Table 3 and Figure 2. This perspective shows already identified patterns in the analysis by country. The first pattern is related to a much greater emphasis in technical competences when compared with transversal competences. The second pattern is related to the emphasis in the definition of expected technical competences of graduates: TC7, TC5, TC2 and TC1, respectively, from knowledge acquisition and its application to design and analysis of systems, products and processes. Finally, it cannot be referred as a pattern, but the most common reference to transversal competences is made to the communication competence.

Table 3. Learning outcomes results – overall perspective of selected European programs

CODE	DESCRIPTION	AVERAGE	STDV
TC1	Production systems analysis and diagnosis	0.05	0.03
TC2	Production systems design / Production planning and control processes design	0.14	0.06
TC3	Planning production and project processes	0.02	0.02
TC4	Monitoring and controlling processes and production system performance	0.01	0.01
TC5	Developing projects, implementing systems, applying methods and procedures	0.24	0.07
TC6	Evaluating production systems and processes	0.02	0.01
TC7	Describing, comparing and selecting technologies, methods and paradigms	0.40	0.11
TC8	Articulating knowledge objects from various areas	0.02	0.02
TRC1	Communication competences	0.04	0.03
TRC2	Ability to deal with the unexpected / Working in environments of uncertainty	0.00	0.00
TRC3	Teamwork competences	0.01	0.01
TRC4	Ability to solve problems	0.01	0.01
TRC5	Leadership competences	0.01	0.02
TRC6	Innovation / Creativity	0.00	0.00
TRC7	Planning and organization competences	0.00	0.00
TRC8	Professional ethic	0.01	0.02
TRC9	Ability to making decisions	0.00	0.00
TRC10	Foreign languages knowledge	0.02	0.04
TRC11	Entrepreneurship	0.00	0.00

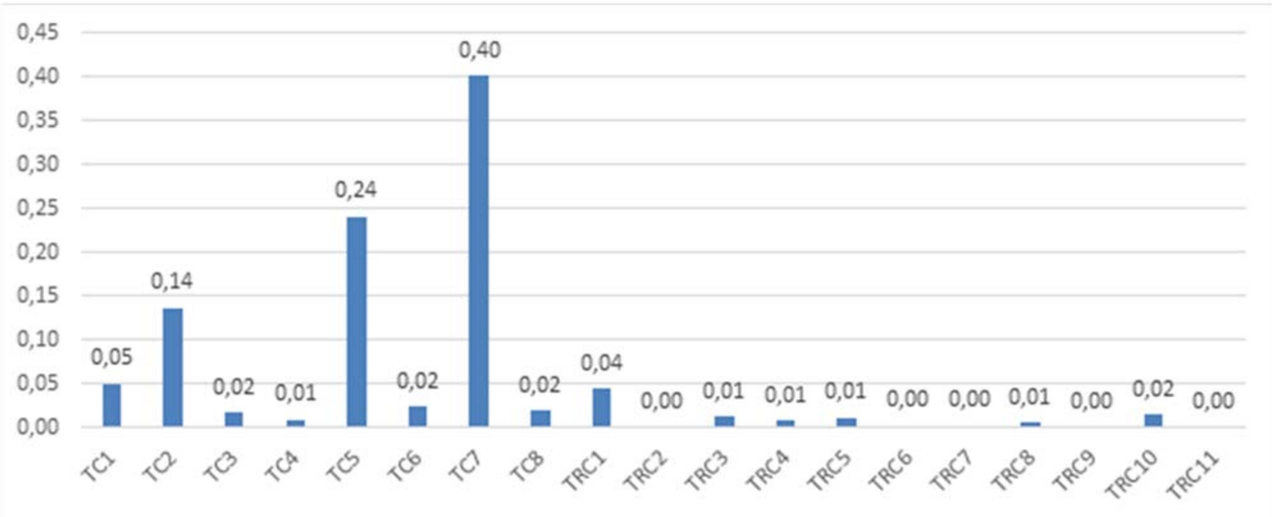

Figure 2. Learning outcomes graph – overall perspective of selected European programs

5 Discussion

The report developed in this part of the project had the intention to present an overall perspective of IE curricula without focusing in any specific trend, area of knowledge or competence. For that reason, the data collection intended to cover a large set of different programs and the analysis was made with a broad framework for the Industrial Engineering area.

The contextual background of master curricula allowed to identify some main master structures for Europe and Thailand. In Thailand, master programs have a duration of 2 years after 4 year-bachelor programs. The program can have between 6 and 8 courses (9 for AIT), ranging from 18 to 24 hours of course work (26 for AIT). The thesis work will vary from 12 to 22 credits, with a duration of 2 or 3 semesters. In Portugal and Romania, the master courses have 120 ECTS (European credit transfer system) in 2 years, after a 3 year-bachelor in Portugal and a 4-year bachelor in Romania. In Poland, the master courses have 90 ECTS in 1.5 years, after a 3.5 year-bachelor. In all cases, the thesis work will be developed during 1 or 2 semesters.

A comprehensive analysis of selected Industrial Engineering and related master degrees curricula was made. This analysis was based on the formal curriculum, using information collected from documents, and allowed to create a perspective on the main areas of knowledge developed in each program and the main types of competences that graduates are expected to develop during their degrees.

Considering the multiple structure models, it seems wise to create a solution that will fit on Thailand formal requirements, trying to approach, as much as possible, to the European models and methods of credit measurement. Thus, it seems that a two-year master proposal would be a best-fit model. This model could have 4 semesters with 4 to 5 courses per semester in the first year.

Recommendation 1: The structure of the master program should have 2 years with 4 semesters, made up of a flexible solution of 4 to 5 courses per semester during the first year.

The analysis of areas of knowledge of the selected programs has an explicit result: the high level of diversity of areas identified in the Industrial Engineering master programs. This is coherent to the overall definition of the area and its multiple professional types of activities. Additionally, it was clear that most of the Thai master programs have a strong emphasis in optimization, and European programs have higher focus on production management and production systems design. Nevertheless, all selected programs from Thailand and European countries have a common emphasis in activities oriented to thesis work.

It seems wise to create a flexible solution made up of a set of courses, with both elective and compulsory courses, that could lead to different profiles. This flexibility would allow for regional and / or personal customization of the profiles. Additionally, the operational level of the curriculum can be implemented in such ways and methodologies that allow different in-depth developments in the areas of knowledge. As an example, Problem and Project-Based Learning (PBL) courses can make the curriculum more flexible, because PBL allows for different learning paths.

Recommendation 2: Create flexible solutions for developing different areas of knowledge in order to have customized solutions related to the personal, regional or future unforeseen requirements.

Regarding the analysis of competences, the first important result is that not every programs define learning outcomes (LO) for each of their courses. Considering that competences are an important factor for the definition of a graduate's profile and also that this is a strong emphasis for the European Higher Education system, it is recommended that this project defines LO for each course. The number of LO should allow a clear identification of the "DNA" of a course and, additionally, should help the student to understand what is expected from him / her and, somehow, how he / she will be assessed. There is not a magical number, but usually a number between 4 and 8 LO can be found in the course descriptions of the European countries.

Recommendation 3: Definition of 4 to 8 learning outcomes for each course.

Technical competences are the core competences of a professional activity, and they represent what makes a person identifiable as being able to execute activities from specific professions. Thus, it is normal that courses implementation give a strong emphasis to the definition of these type of competences. Nevertheless, in the last decades, a stronger emphasis is being put on the need to develop professionals able to perform with higher efficiency and efficacy right from the beginning of their professional activity. Due to this, the European Higher Education system has been stressing the importance of defining the expected transversal competences that graduates should develop in their degrees. Thus, the following recommendation is that this project give due importance to the development of transversal competences, which are required by the professional activities. The development of competences need the implementation of specific educational strategies to be effective, and this should be considered in the curriculum development.

Recommendation 4: Explicit definition of learning outcomes for transversal competences. Additionally, explicit consideration of teaching and learning methods for the development of transversal competences.

This report was based on the formal level of curriculum, which is the most visible part of the programs. Nevertheless, one should be aware that the development of competences is mainly related to operational level of curriculum, including the way it is implemented by the teacher in the classroom, and the way it is experienced by the students. This awareness reveals a fifth recommendation: it is essential to align the formal and the operational level of the curricula in order to approach, as much as possible, the desired ideal curriculum.

Recommendation 5: Explicit and clear alignment of the elements of the curriculum, and explicit linkage between the operational, the formal and the ideal levels of the curriculum is a key factor for effective development of competences.

This report provides helpful inputs for the construction of the perspective about the current state of learning and teaching methods and for developing some recommendations based on partner's existing best practices and state of the art best practices. This can then be compared with the industry and students identified needs for Industry 4.0, as a starting point to identify gaps, which should be addressed in the identification of competitive factors and final recommendations for curriculum development.

6 Acknowledgements

This work is based on outcomes of project "Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry (MSIE 4.0)" that has been funded with support from the European Commission (Project Number: 586137-EPP-1-2017-1-TH-EPPKA2-CBHE-JP). This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein. The authors would like to thank to the members of the consortium and all that made possible to collect the data we used in this paper.

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the Project Scope UIDCEC003192019.

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