WP 1 - Gap Analysis

Outcome 1.2 Comprehensive analysis of MSIE curricula being offered in Thailand and in EU partner countries

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1 Executive Summary

The current report presents a comprehensive analysis of MSIE curricula, taking into account the aspects to be considered in the new foreseen curricula. Thus, this report starts presenting a context background regarding curriculum conceptual knowledge and professional practice in Industrial Engineering. Additionally, presents a short overview about Higher Education contexts in Thailand and in Europe. The structure of higher education in all countries participating in the project are different. For start, it is expected that all students enrolled in an industrial engineering master program have been through a different number of years of bachelor studies, ranging from three years in Portugal, 3.5 years in Poland (Engineer degree), to 4 years in Romania and Thailand. Moreover, the way the learning time is measured is also significantly different. In Thailand, credits are measured by class hours and in Europe the European credit system is based on the total learning time, including non-class time. Nevertheless, the master programs have a common structure in both Thailand and European countries, consisting of a two-year program (exception for Poland with 1.5-year program), in which the thesis is developed during two semesters of the second year.

The analysis was based in two main dimensions of curriculum, the areas of knowledge and the learning outcomes. Learning outcomes are related to the competences students are expected to develop in each course. The WP1 team collected and analysed 12 Thai master programs and 14 European master programs. The presentation and analysis of the 26 master programs allowed to identify a high level of diversity regarding main areas of knowledge and competences of each program. This is coherent with the overall definition of the area and its multiple professional type of activities. Additionally, it was clear that most of the Thai master programs have a strong emphasis in optimization, and European programs have higher emphasis on production management and production systems design.

The analysis of curricula show that in general, Thai programs define expected outcomes for a program but do not explicitly define it for every course. Additionally, there is a tremendous lack of attention in transversal competences in all programs. Considering the main current trends in higher education due to the importance of this group of competences in professional activities, it is important to make them explicit in programs. Moreover, the development of competences requires the definition of learning outcomes and the application of active learning strategies in the curriculum.

2 Introduction

WP1 is aimed to provide comparative analysis of the current situation concerning the MSc curricula in Industrial Engineering (IE) offered in Thai and European (EU) partner countries universities, the identification of the gaps between the real needs of the industry, the student needs and the actual offered curricula. Within this context, Task 1.2 focus on analysing MSIE curricula, as well as the learning and teaching methods being offered currently in the project partners' countries (Thai and EU). This outcome will be specifically related to the analysis of the current IE curricula being offered, and learning and teaching methods will be part of the report related to Outcome 1.3. Nevertheless, as both reports are related to Task 1.2, they will be based on the same set of programs, will have similar structures whenever possible and may have overlapping contents.

This task is related to the analysis of the current state of the curricula in Europe and Thailand, regarding Industrial Engineering overall area. At this point, it will not be related to any specific trend, as it intends to give an overall perspective of the IE master programs in Thailand and Europe. Its results should be useful for gap analysis and identification of competitive factors for the construction of MSIE master courses in future phases of the MSIE4.0 project.

2.1 Context Background

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 (Lima, Mesquita, Amorim, Jonker, & Flores, 2012; Mesquita, Lima, Flores, Marinho-Araujo, & Rabelo, 2015). The diversity within 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 (e.g. connect 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 project is contributing for this purpose, aiming at developing a modernised curriculum of Master's degree program with international recognition in IE to support sustainable smart industry in Thailand with collaboration with EU partners.

In this context, Task 1.2 intends to provide a comprehensive analysis of MSIE curricula, contributing 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 and Sustainability, 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 the teaching and learning experiences, the process of its development - design, development and evaluation - and 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 the MSIE4.0 project:

1. 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 and strategies to communicate the content to the students; 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.
2. 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).

In the context of the Task 1.2, inputs related to the formal and operational curriculum level was essential to analyse the existing master programs in Thailand and Europe. It is expected that the main result of the analysis will provide new inputs for the new curricula at the ideal level.

2.1.1 Higher Education in Europe - a contextualised brief perspective

For a better understanding about the curriculum analysis, a short overview of both Higher Education contexts (Thailand and Europe) must be addressed, specifically regarding to master curriculum principles, structure and organization.

The European Higher Education system is characterized by the principles of the Bologna Process (Bologna_Declaration_CRE, 1999), focusing on:

- introduction of the three cycle system: bachelor (3 years or 4 years), master (2 years or one and half year) and doctorate (3/4 years)
- introduction of *European Credit Transfer and Accumulation System* (ECTS): to enhance the recognition of qualifications and periods of study
- strengthened quality assurance, in order to equip students with the knowledge, skills and core transferable competences they need to succeed after graduation

One European partner of the MSIE4.0 project, CUT – Poland, have 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. Another European partner, UPB – Romania, have a 4-year bachelor followed by 2 years of master (4+2 model), 240 + 120 ECTS. The other European partner, UMinho – Portugal, have a structure of 3 years of bachelor (180 CTS) followed by 2 years of master (120 ECTS), i.e. a model of 3+2. We will assume this structure throughout the text, unless explicitly stated, when referring to the European countries in a generic way. At least another model could be found in some European countries of 4-year bachelor followed by 1-year master (model 4+1).

In the scope of the Task 1.2, 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, and have the remaining time of autonomous study work.
- One academic year has 40 weeks and one semester has 20 weeks, including two to three weeks for an assessment period.
- 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 two years - 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 six courses with five ECTS. The dissertation course is developed approximately during one and a half semester, at the end of second year, and corresponds to 40 ECTS. Figure 1 illustrates the structure of the master years of the Industrial Engineering and Management Integrated Master (IEM-IM). It is important to note that both the number of courses and the corresponding ECTS can be different from this example, but they must sum up 30 ECTS per semester and 120 ECTS for a two-year master program.

<table>
<tr><td>Year</td><td colspan="2">Semester 1</td><td>Semester 2</td></tr>
<tr><td>2</td><td>4 courses of 5 ECTS</td><td colspan="2">IEM Master Dissertation of 40 ECTS</td></tr>
<tr><td>1</td><td colspan="2">6 courses of 5 ECTS</td><td>6 courses of 5 ECTS</td></tr>
</table>

Figure 1. Structure of the Master years of the Industrial Engineering and Management Integrated Master

2.1.2 Higher Education in Thailand – a contextualised brief perspective

The Higher Education system in Thailand has different approaches to the master programs structure between AIT and the other partners, and they are all different from European countries. One important issue is that master students are expected to have gone through bachelor studies of 4 years before entering a master program. In Europe, considering the model 3+2, students go through bachelor studies of 3 years. A common characteristic is related to the fact that both Thai and European master programs can be made up of 2 years – 4 semesters, but almost every other structural characteristics are different. All Thai partners have a credit structure equivalent to the lecture hours per week for a course. As an example, a course of three credits corresponds to a course that have 3 hours per week of lectures. When considering laboratories' classes, it is usual to assign one credit to 3-hours lab. Additionally, AIT still assigns a credit to two hours of workshop.

- The academic semester has a duration of 15 to 16 weeks, including one week of assessment / exams
- 1 credit corresponds to 1-hour lecture
- A master program in all partners, except AIT, is made of 36 credits
- A master program in AIT is made of 48 credits

Master programs in all partners, except AIT, are made of 36 credits. A master program in AIT is made of 48 credits. AIT have a structure of 26 hours (credits) of course work (Figure 2), divided by 4 courses of 3 credits per semester in first year and one course of 2 credits in semester 3. The thesis work corresponds to 22 hours (credits).

Year	Semester 1	Semester 2	Sum up:
2	1 course of 2 credits + 10 hours of thesis work	12 hours of thesis work	22 hours of thesis
1	4 courses of 3 credits	4 courses of 3 credits	26 hours of coursework

Figure 2. Structure of a Master program in AIT

A master program in PSU is made of 36 credits. These credits are structured in 18 hours (credits) of coursework (Figure 3), divided by 4 courses of 3 credits in semester one and 2 courses of 3 credits in the second semester. The thesis work correspond to 18 hours (credits), starting in semester 2 of the first year.

Year	Semester 1	Semester 2	Sum up:
2	6 hours of thesis work	6 hours of thesis work	18 hours of thesis
1	4 courses of 3 credits	2 course of 3 credits + 6 hours of thesis work	18 hours of coursework

Figure 3. Structure of a Master program in PSU

A master program in TU is made of 36 credits. These credits are structured in 18 hours (credits) of coursework (Figure 4), divided by 3 courses of 3 credits in each semester of the first year. The thesis corresponds to 18 hours (credits), starting in the first semester of the second year.

Year	Semester 1	Semester 2	Sum up:
2	9 hours of thesis work	9 hours of thesis work	18 hours of thesis
1	3 courses of 3 credits	3 courses of 3 credits	18 hours of coursework

Figure 4. Structure of a Master program in TU

A master program in KMUTNB, KKU and CMU is made of 36 credits. These credits are structured in 24 hours (credits) of coursework (Figure 5), divided by 4 courses of 3 credits in both semesters of the first year. The thesis corresponds to 12 hours (credits) developed during both semesters of the second year.

Year	Semester 1	Semester 2	Sum up:
2	6 hours of thesis work	6 hours of thesis work	12 hours of thesis
1	4 courses of 3 credits	4 courses of 3 credits	24 hours of coursework

Figure 5. Structure of a Master program in KMUTNB, KKU and CMU

2.2 Methodological Approach

The main activities of Task 1.2 are the following:

- Task 1.2.1 Reviewing MSIE curricula being offered currently in Thailand
- Task 1.2.2 Reviewing teaching and learning methods being applied currently in Thailand
- Task 1.2.3 Reviewing MSIE curricula being offered currently in partners' countries
- Task 1.2.4. Reviewing teaching and learning methods being applied in partners' countries
- Task 1.2.5 Analysing curricula, and teaching and learning methods

Particularly this report will focus on Task 1.2.1, 1.2.3 and part of 1.2.5. The output of these tasks will contribute to an understanding about the MSIE curricula in Thailand and European countries, in order to create a ground base for the identification of the gap between competences' needs for Industry 4.0 and sustainability and the academic development of Industrial Engineering master students.

In the scope of this project, the diversity of institutions and programs to be analysed implies a definition of multiple sources and methods, as recommended by Wolf, Hill, and Evers (2006). With this in mind, and focusing on formal level of the curriculum (Goodlad, 1979), several types of information will 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 essentials to analyse the IE competences in the context of Industry 4.0 and Sustainability.

As planned in this task, there is the need to collect different information regarding formal curriculum (documents related to the master program) and operational curriculum (best practices related to teaching and learning strategies implemented in those programs). In the first phase, the WP1 team developed instruments for collecting information (Figure 6).

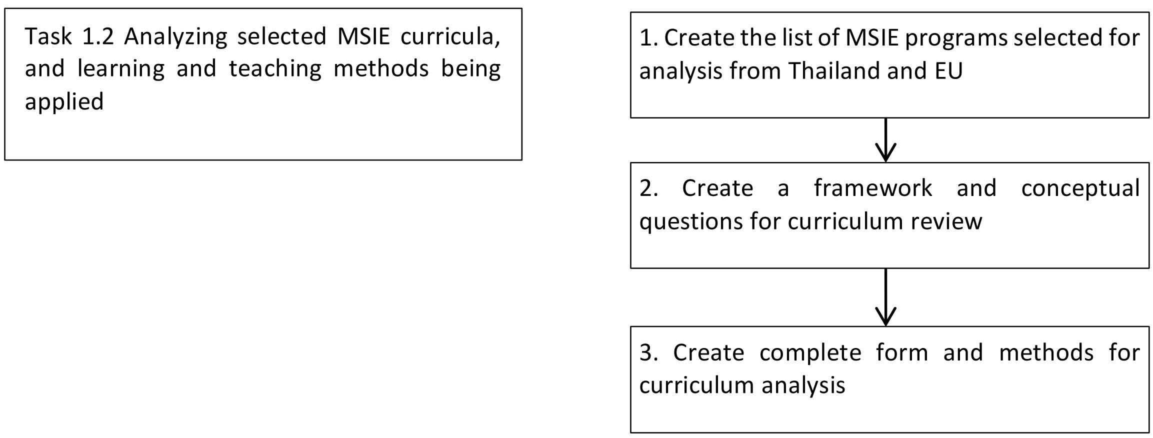

Figure 6. Steps 1-3 of Task 1.2 plan

An Excel template was developed and distributed among the partners to collect information about curriculum structure, areas of specialization and learning outcomes. Other form was developed to collect information about best practices of educational experiences based on innovative learning environments with a student centred approach (i.e. active learning strategies).

Figure 7 presents a schematic representation of the method followed by the WP1 team, during the execution and analysis phases. It is important to highlight the fact that the data was collected simultaneously, but this report will focus on the data of the formal curricula analysis, and the Outcome 1.3 will focus on the analysis of teaching and learning methods.

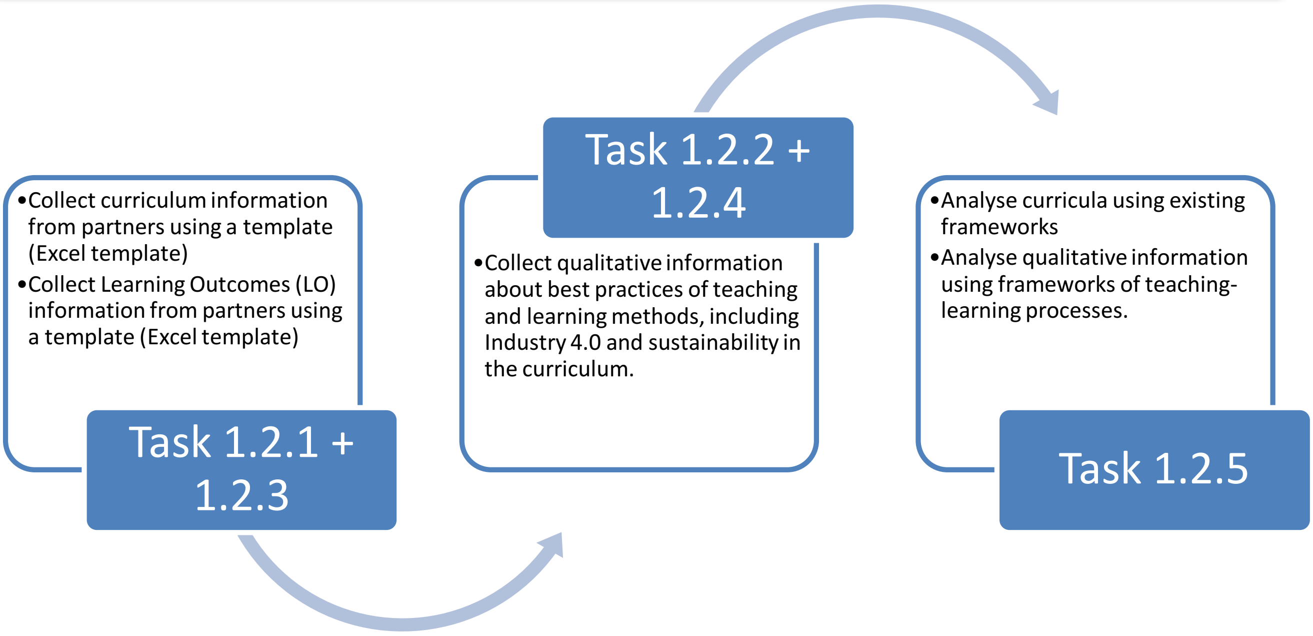

Figure 7. Execution and analysis phases of Task 1.2 methodology

Reviewing MSIE curricula (Tasks 1.2.1 and 1.2.3) will be based on data collected from partners, using an Excel file as a template. First, we collect information from the courses, class types, hours of contact and credits. In a second sheet, we ask information from learning outcomes in order to identify the expected competences to be developed by the graduates.

The collection of data about best practices on teaching and learning methods, including Industry 4.0 and sustainability (Tasks 1.2.2 and 1.2.4) will be done in a qualitative way, asking partners to fill a form for identified best practice in their context. These best practices should be related to student centred learning strategies (active learning), including Industry 4.0 or sustainability aspects. We planned to collect, from each project partner, approximately three best practices. These best practices will be analysed using a qualitative approach based on a predefined framework made of active learning principles and a glossary of practice's classification. This analysis will be presented in report for Task 1.2, Outcome 1.3.

Finally, the data was analysed using a mixed approach between a quantitative approach (descriptive statistics) and qualitative data (content analysis).

2.2.1 Framework for Analysis

The learning outcomes are understood 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). In this sense, from the description of the courses and the description of the courses' learning outcomes it is possible to identify the areas of knowledge and the competences that are being considered in the context of the different programs.

Regarding to the areas of knowledge analysis, part of Task 1.2.5, a framework of analysis was created based on the Industrial Engineering and Management areas of knowledge presented by Lima et al. (2012). 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:

1. **Automation -** engineers should solve problems, repair and maintain automated industrial equipment, such as computer numerical control (CNC) equipment and robots.
2. **Computer and Information Systems (*)** - focuses on the application of computers in a business environment with an emphasis on the analysis and design of business information systems.

3. **Economics Engineering** - the application of economic concepts in the engineering problem solving process; for example, analysing the economics of different alternatives, analysing industrial costs and being involved in the financial management of organizations.
4. **Ergonomics and Human Factors –** focuses on the understanding of interactions among humans and other elements of a system, and the application of theory, principles, data, and other methods to systems or product design in order to optimize human well-being and overall system performance.
5. **Industrial Engineering and Management (*) –** implies an interdisciplinary approach, in which several elements of IE are included in the same context and that could not be classified in only one of the other areas. Usually used for classification of interdisciplinary projects, dissertations, internships and other similar approaches.
6. **Industrial Optimization -** link between mathematics, engineering and management, using an operations research, heuristics or simulation, for achieving the best possible solution for a problem for industrial and service companies, in terms of a specified objective
7. **Innovation and Entrepreneurship (*) –** focuses on designing or improving products, services, and markets, as well as on the development of new methods of production and new management systems.
8. **Maintenance -** management process of organization, planning and implementation of corrective maintenance, preventive maintenance, and continuous improvement of industrial and service business organizations
9. **Marketing -** design, pricing, promotion, and distribution of goods to create transactions with businesses and consumers
10. **Product Design -** the conversion of a need or innovation into a product, process, or service that meets both the enterprise and customer expectations. The design process consists of translating a set of functional requirements into an operational product, process or service
11. **Production Management -** design, improvement and management of systems that deliver products and services. This area is related to the design and improvement of production systems and the activities of production planning and control activities for the efficient and effective use of those production systems
12. **Project Management -** application of knowledge, skills, tools, and techniques to project activities to meet the project requirements (scope, quality, risks, human resources, amongst others)
13. **Quality -** analysis of a manufacturing system at all stages to maximize the quality of the process itself and the products it produces
14. **Research Methods (*) –** application of methods of data collection and data analysis in order to develop a consistent and feasible research project.
15. **Sociology and Law (*) –** explore the social and organization aspects of the society, industries and services, contributing for an understanding about how it works.
16. **Supply Chain Management** - design, planning, execution, control and monitoring of supply chain activities with the objective of creating net value for industrial and service companies
17. **Sustainability (*) –** environmental, economic, social and cultural dimensions must be considered in all dimensions of IE (project, improvement and management of systems; people, materials, equipment, financial resources, information and energy; products and services).
18. **Systems Design (*) -** architecture, modules, interfaces, and data for a system to satisfy specified requirements.
19. **Other (*) –** refers to other areas that can be identified in the courses and 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 and Management was considered based on Mesquita et al. (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

2.2.2 Data collection summary

The following tables summarise the data collected and analysed in this report. Table 1 refers to the data of Industrial Engineering (IE), or related, 12 programs that were selected and analysed from Thailand. Only one of the programs define the courses LO. The column Areas of Knowledge present the number of programs that was possible to analyse regarding areas of knowledge.

Table 1. Summary of the Thailand IE programs' curricula analysed in this report

Country - University	Universities	Programs	Programs with areas of knowledge	Programs with courses' LO
Thailand – AIT	1	1	1	1
Thailand – KU	1	1	1	-
Thailand – CMU	1	1	1	-
Thailand – MFU	1	1	1	-
Thailand – KKU	1	1	1	-
Thailand – SUT	1	1	1	-
Thailand – UBU	1	1	1	-
Thailand – KMUTNB	1	1	1	-
Thailand – BUU	1	1	1	-
Thailand – KMITL	1	1	1	-
Thailand – PSU	1	1	1	-
Thailand – TU	1	1	1	-
	12	**12**	**12**	**1**

Table 2 summarizes the data of Industrial Engineering, or related, 14 programs that were selected and analysed from European countries. Three of these programs do not define LO for each course and for that reason they were not considered in the analysis.

Table 2. Summary of the European IE programs' curricula analysed in this report

Country - University	Universities	Programs	Programs with areas of knowledge	Programs with courses' LO
Portugal – UMinho	1	3	3	3
Portugal – UPorto	1	1	1	1
Portugal – UAveiro	1	1	1	1
Poland – CUT	1	1	1	1
Poland – AGH	1	1	1	1
France – IPG	1	1	1	1
Romania – UPB	1	3	3	-
Romania – UGhAIasi	1	1	1	-
Madrid – UPM	1	1	1	-
UK – UG	1	1	1	1
	10	**14**	**14**	**9**

3 Results – Areas of Knowledge analysis

The results related to the areas of knowledge will be presented in the next sections, based on the framework analysis previous described. The course name / description was the key-information to help the experts (team of 5 researchers with a different background in IE) to identify the areas of knowledge. The weight of the areas of knowledge was defined considering the following statement: each course individually correspond to 1 point and the classification focuses on the main area of knowledge that the course represent. In some cases, two areas of knowledge (maximum) might be considered for the same course. For instance, "Supply Chain Optimization" is one course of one of the UMinho programs and was classified with a weight of 0.5 as Industrial Optimization and a weight of 0.5 as Supply Chain Management.

An additional observation must be considered regarding to Industrial Engineering and Management (AK5). According to the definition presented in the framework, this area of knowledge implies an interdisciplinary approach, in which several elements of IE are included in the same context and could not be classified in only one of the other areas. Usually used for classification of interdisciplinary projects, dissertations, internships and other similar approaches. For this reason, IEM represents a significant weight in all programs.

After the application of the classification schema, a sum of the values was computed for each area of each program. Finally, the percentage of each area in each program was calculated and presented in tables and charts in following sections.

The analysis of the results was organized in two different sections. The first focuses on Thailand context and the second part focuses on European context. A total of 26 programs were analysed.

3.1 Areas of knowledge – Thailand selected programs

The results of the areas of knowledge in the Thailand context is presented in this section. To clarify the presentation, the results were organised in two parts: programs related to Thailand partner universities (6) and programs related to other Thailand universities (6). At the end, an overall analysis is presented, joining the results of both parts.

3.1.1 Thailand - partner universities

The Thailand partner universities are AIT - Asian Institute of Technology, CMU - Chiang Mai University, KKU - Khon Kaen University, KMUTNB - King Mongkut's University of Technology North Bangkok, PSU - Prince of Songkla University and TU - Thammasat University. The results of the six programs analysed are presented in Table 3 / Figure 8.

Developing an individual analysis, it is possible to identify that, in some cases, the program has only one predominant area of knowledge and, in other cases, have two or more. For instance, 21% of the AIT program have a focus on Industrial Optimization. Nevertheless, the results show a group of four areas very representative within the program (11%), namely Automation, Systems Design, Quality and Production Management.

In regard to CMU, two main areas are the focus of the program: Quality (17%) and Industrial Optimization (14%). TU presents similar results with a weight of 15% regarding Quality and 12% regarding Industrial Optimization. TU program comes up with other area also with 12%, Product Design.

Looking at the other programs some differences can be identified. For instance, KMUTNB presents a strong focus on Systems Design (17%) and IEM and Industrial Optimization (14%). PSU has a focus on Industrial Optimization (14%) and Computer and Information Systems (12%).

From these six programs, KKU program is the one that reveals the highest weight in Supply Chain Management (16%). Other two significant areas are Industrial Optimization and Production Management, clearly represented in 36% of the program (18% each).

Table 3. Areas of Knowledge Results – Thailand Partner Universities

Scientific Area	AREA CODE	AIT	CMU	KKU	KMUTNB	PSU	TU
Automation	AK1	0.11	0.00	0.00	0.00	0.05	0.04
Comp. and Inf. Systems	AK2	0.01	0.07	0.05	0.02	0.12	0.00
Economics Engineering	AK3	0.05	0.04	0.02	0.05	0.00	0.08
Ergonomics and Human Factors	AK4	0.00	0.04	0.01	0.12	0.10	0.10
IEM	AK5	0.11	0.05	0.16	0.14	0.21	0.08
Industrial Optimization	AK6	0.21	0.14	0.18	0.14	0.14	0.12
Innovation and Entrepr.	AK7	0.00	0.03	0.00	0.00	0.05	0.00
Maintenance	AK8	0.00	0.02	0.03	0.00	0.05	0.00
Marketing	AK9	0.00	0.01	0.03	0.00	0.00	0.00
Product Design	AK10	0.09	0.08	0.01	0.04	0.07	0.12
Production Management	AK11	0.11	0.10	0.18	0.11	0.04	0.10
Project Management	AK12	0.00	0.02	0.00	0.02	0.00	0.08
Quality	AK13	0.11	0.17	0.05	0.04	0.07	0.15
Research Methods	AK14	0.00	0.02	0.03	0.02	0.02	0.02
Sociology and Law	AK15	0.00	0.01	0.00	0.00	0.02	0.00
Supply Chain Management	AK16	0.05	0.08	0.16	0.11	0.02	0.04
Sustainability	AK17	0.05	0.02	0.03	0.04	0.00	0.06
Systems Design	AK18	0.11	0.11	0.05	0.17	0.04	0.04
Others	AK19	0.00	0.00	0.00	0.00	0.00	0.00

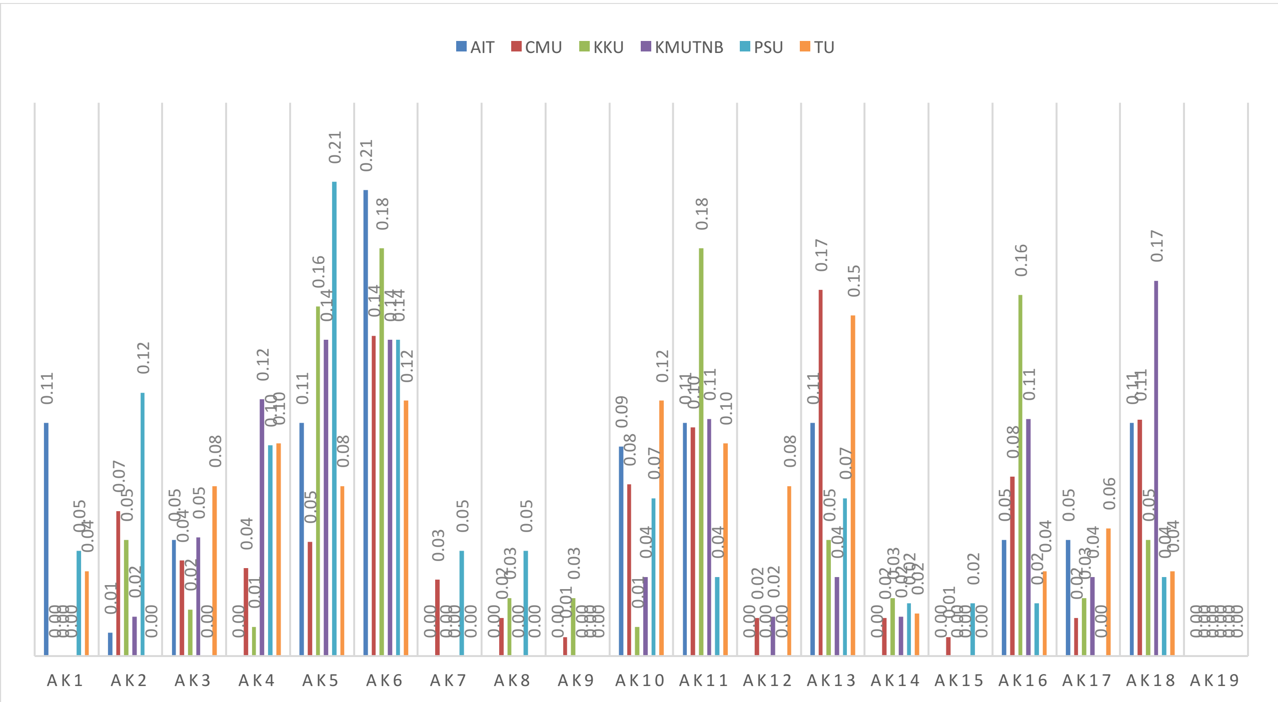

Figure 8. Areas of Knowledge Graph - Results from Thailand Partner Universities

3.1.2 Thailand - other selected programs

Data from another 6 programs in Thailand universities were analysed, namely KU - Kasetsart University, MFU - Mae Fah Luang, SUT - Suranaree University of Technology, UBU - Ubon Ratchathani University, BUU - Burapha University and KMITL - King Mongkut's Institute of Technology Ladkrabang. The main results are presented in Table 4 and Figure 9.

It is important to emphasize two programs, taking into account the strong weight in one specific area. MFU program presents a total of 48% in Supply Chain Management and KU program a total of 39% in Industrial Optimization. The MFU program has one course that was included in the category "others" (AK19) and it was the only case identified in Thailand context. That specific course refers to "Independent Study".

The programs from SUT and UBU presents similar results in terms of predominant areas of knowledge. Both focus on Industrial Optimization and Systems Design. At SUT represents 46% of the program (23% each) and at UBU 31% (Industrial Optimization 19% and Systems Design 12%).

In the remaining programs it is possible to identify some interesting differences. BUU focus on Industrial Optimization and Production Management both with a weigh of 12%. KMITL focus on three main areas of knowledge: Industrial Optimization (15%), Economic Engineering (13%) and Product Design (13%).

Table 4. Areas of Knowledge Results – other selected Thailand programs

Scientific Area	AREA CODE	BUU	SUT	KMITL	UBU	MFU	KU
Automation	AK1	0.03	0.09	0.05	0.05	0.00	0.01
Comp. and Inf. Systems	AK2	0.07	0.05	0.01	0.00	0.07	0.04
Economics Engineering	AK3	0.04	0.04	0.13	0.05	0.07	0.09
Ergonomics and Human Factors	AK4	0.04	0.07	0.09	0.05	0.00	0.00
IEM	AK5	0.15	0.11	0.13	0.14	0.09	0.12
Industrial Optimization	AK6	0.12	0.23	0.15	0.19	0.03	0.39
Innovation and Entrepr.	AK7	0.08	0.00	0.02	0.00	0.03	0.00
Maintenance	AK8	0.05	0.00	0.02	0.10	0.00	0.05
Marketing	AK9	0.03	0.00	0.00	0.00	0.02	0.00
Product Design	AK10	0.05	0.00	0.13	0.07	0.00	0.02
Production Management	AK11	0.12	0.04	0.06	0.10	0.04	0.02
Project Management	AK12	0.03	0.04	0.02	0.00	0.02	0.02
Quality	AK13	0.05	0.04	0.06	0.05	0.00	0.06
Research Methods	AK14	0.04	0.00	0.02	0.05	0.04	0.02
Sociology and Law	AK15	0.01	0.00	0.00	0.00	0.02	0.00
Supply Chain Management	AK16	0.05	0.04	0.06	0.05	0.48	0.07
Sustainability	AK17	0.00	0.02	0.00	0.00	0.00	0.01
Systems Design	AK18	0.03	0.23	0.06	0.12	0.03	0.07
Others	AK19	0.00	0.00	0.00	0.00	0.04	0.00

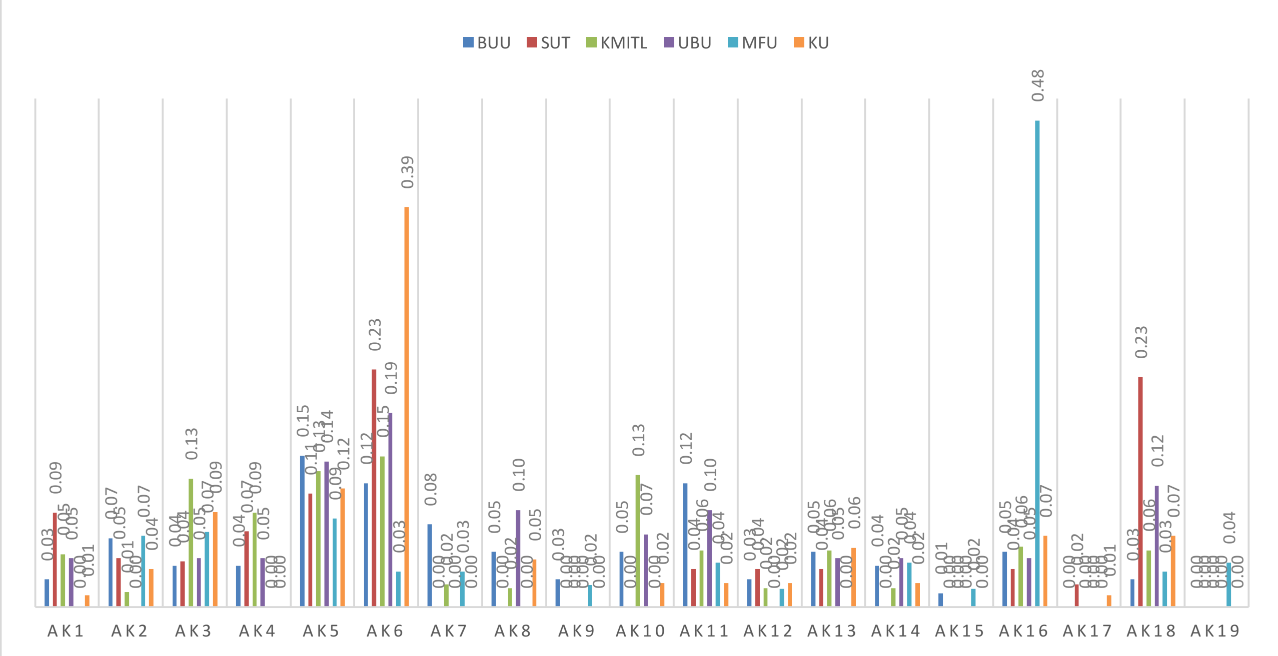

Figure 9. Areas of Knowledge Graph - Results from other selected Thailand programs

3.1.3 Thailand - selected programs overall perspective

An overview of the predominant areas of knowledge in the 12 Thai programs is provided in this section. The main results are presented in Table 5 and Figure 10, in which is possible to notice the significant impact of Industrial Optimization in all programs in Thailand. This idea is confirmed by the standard deviation identified in this area of knowledge.

Another interesting conclusion is related to the area of Supply Chain Management. The standard deviation shows the diversity in distribution between all programs, which confirms the analysis presented in the previous sections, where the programs with focus on this area were identified.

Regarding to the IEM area of knowledge, a low standard deviation is revealed which indicates that most of the Thai programs have a similar number of courses classified as IEM. Nevertheless, the programs have different approaches: thesis, internship, seminars, amongst other.

In summary, the results show the diversity of areas of knowledge in Industrial Engineering context and, consequently, the diversity of the programs in which is possible to identify common issues and also differences.

Table 5. Areas of Knowledge – Thailand selected programs overall perspective

Area of Knowledge	AREA CODE	THAI PROGRAMS	THAI PROGRAMS STDV
Automation	AK1	0.04	0.03
Comp. and Inf. Systems	AK2	0.04	0.03
Economics Engineering	AK3	0.06	0.03
Ergonomics and Human Factors	AK4	0.05	0.04
IEM	AK5	0.12	0.04
Industrial Optimization	AK6	0.17	0.08
Innovation and Entrepr.	AK7	0.02	0.03
Maintenance	AK8	0.03	0.03
Marketing	AK9	0.01	0.01
Product Design	AK10	0.06	0.04

Area of Knowledge	AREA CODE	THAI PROGRAMS	THAI PROGRAMS STDV
Production Management	AK11	0.08	0.04
Project Management	AK12	0.02	0.02
Quality	AK13	0.07	0.05
Research Methods	AK14	0.02	0.01
Sociology and Law	AK15	0.01	0.01
Supply Chain Management	AK16	0.10	0.12
Sustainability	AK17	0.02	0.02
Systems Design	AK18	0.09	0.06
Others	AK19	0.00	0.01

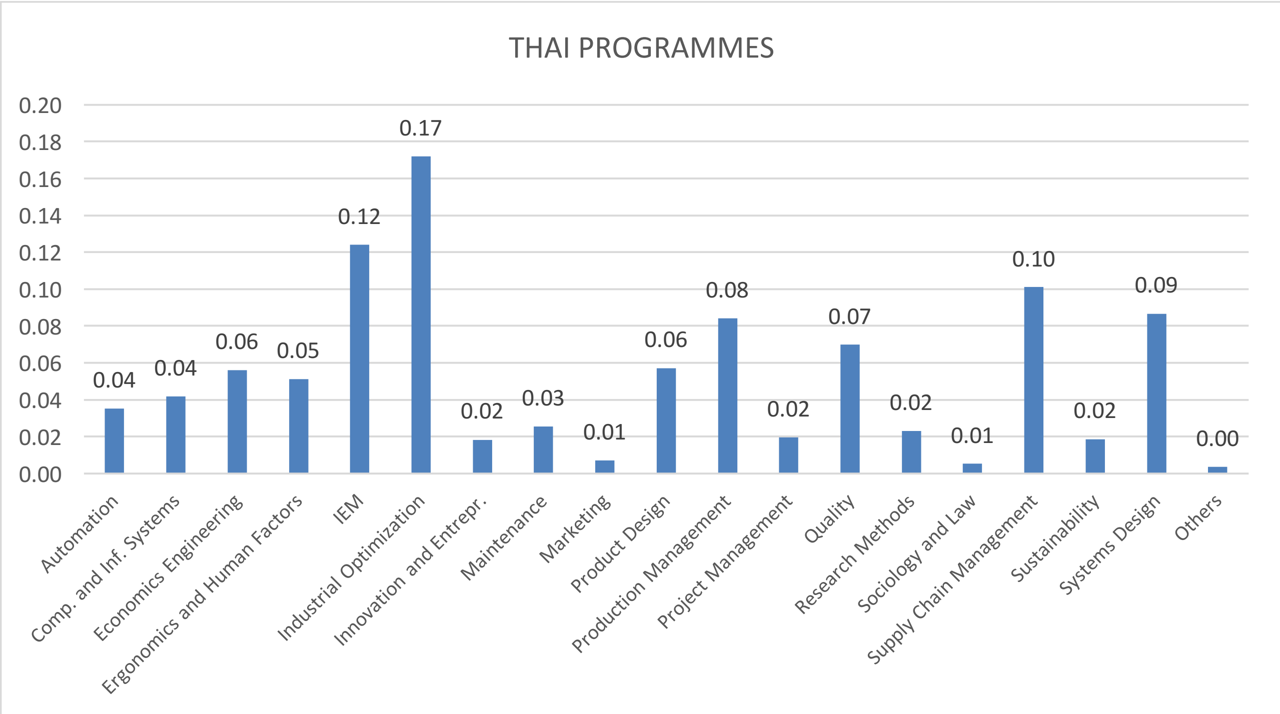

Figure 10. Areas of Knowledge Graph - Thailand selected programs overall perspective

3.2 Areas of knowledge analysis – European selected programs

The results of the areas of knowledge in the European context is presented in this section. To clarify the presentation, the results were organised by three countries with project partners, namely Poland (2 programs), Portugal (5 programs), Romania (4 programs), and other from selected European programs (3 programs). Thus, a total of 14 programs were analysed. At the end, an overall perspective is presented, joining the results of all parts.

Similar to the Thai context, and as expected, IEM is an area of knowledge strongly represented in all programs. As previously referred, this is expected because this area represents the thesis work and other interdisciplinary projects or internships.

3.2.1 Poland – selected programs

Two programs from Poland were analysed: CUT - Częstochowa University of Technology and AGH - University of Science and Technology. Table 6 and Figure 11 illustrates the results from both programs.

One specific area arise from the results in both programs, Production Management, with a weight of 17% at CUT and 24% at AGH. At AGH, courses related to Sociology and Law have an important role in the curricula (16%). This program also presents indicators at category "Others", which in this case are related to "Foreign language (A1 English)" and "Foreign language (B1 English)".

Table 6. Areas of Knowledge Results – Poland selected programs

Area of Knowledge	AREA CODE	CUT_MPE	AGH_MPE
Automation	AK1	0.00	0.00
Comp. and Inf. Systems	AK2	0.09	0.06
Economics Engineering	AK3	0.04	0.06
Ergonomics and Human Factors	AK4	0.04	0.01
IEM	AK5	0.13	0.04
Industrial Optimization	AK6	0.09	0.04
Innovation and Entrepr.	AK7	0.08	0.04
Maintenance	AK8	0.00	0.00
Marketing	AK9	0.00	0.02
Product Design	AK10	0.04	0.08
Production Management	AK11	0.17	0.24
Project Management	AK12	0.04	0.04
Quality	AK13	0.04	0.00
Research Methods	AK14	0.04	0.04
Sociology and Law	AK15	0.05	0.16
Supply Chain Management	AK16	0.00	0.00
Sustainability	AK17	0.04	0.00
Systems Design	AK18	0.09	0.08
Others	AK19	0.00	0.08

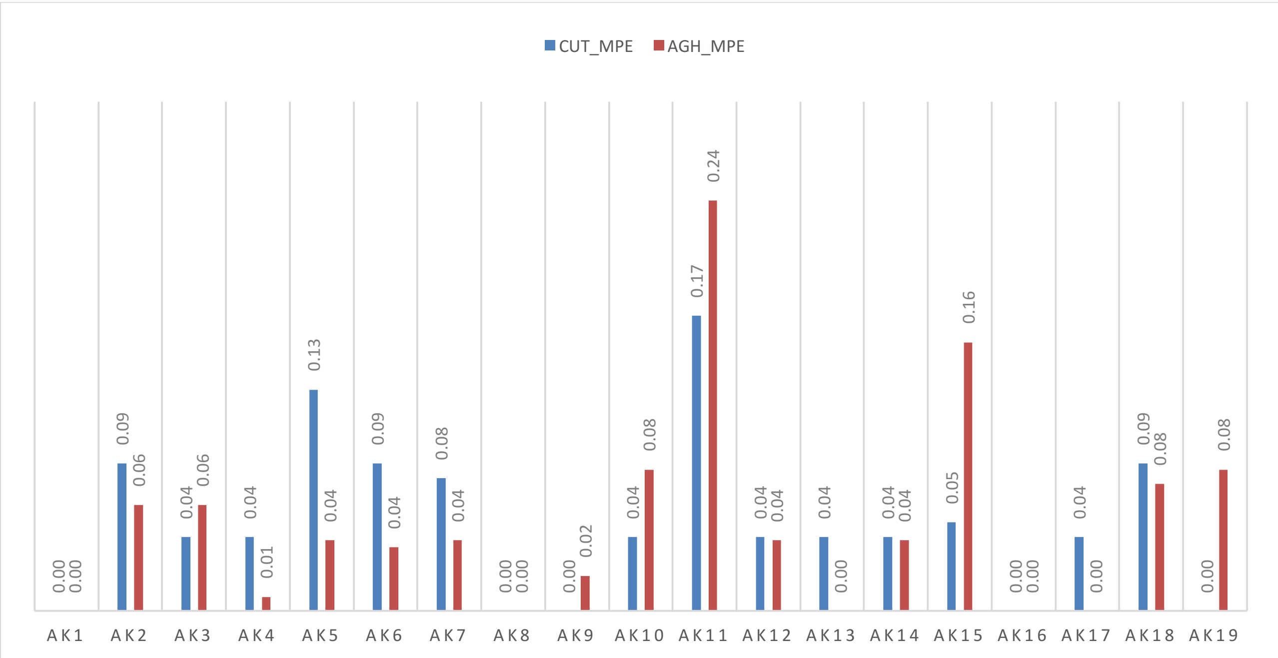

Figure 11. Areas of Knowledge Graph – Results from Poland selected programs

3.2.2 Portugal – selected programs

The results from the Portuguese context includes five programs, in which three are from University of Minho (UMinho_IEM; UMinho_IE; UMinho_ES), one from University of Porto (UPorto_IEM) and other from University of Aveiro (UAveiro_IEM). The summary of analysis is presented in Table 7 and Figure 12.

The focus on Production Management previously noticed in the Polish context is also possible to found in two programs at UMinho, namely UMinho_IEM (25%) and UMinho_IE (20%). The other program (UMinho_ES) has a strong emphasis on Supply Chain Management (25%) and Industrial Optimization (14%). Regarding UPorto_IEM the main focus is Industrial Optimization (19%).

The UAveiro_IEM program reveals a different perspective in the curricula, focusing on four areas of knowledge, specifically Computer and Information Systems (17%), Innovation and Entrepreneurship (16%), Sustainability (15%) and Systems Design (15%).

Table 7. Areas of Knowledge Results – Portugal selected programs

Area of Knowledge	AREA CODE	UMinho_IEM	UMinho_IE	UMinho_ES	UPorto_IEM	UAveiro_IEM
Automation	AK1	0.04	0.00	0.00	0.00	0.05
Comp. and Inf. Systems	AK2	0.08	0.07	0.09	0.06	0.17
Economics Engineering	AK3	0.00	0.07	0.06	0.06	0.00
Ergonomics and Human Factors	AK4	0.05	0.07	0.00	0.00	0.00
IEM	AK5	0.15	0.13	0.19	0.13	0.05
Industrial Optimization	AK6	0.08	0.11	0.14	0.19	0.07
Innovation and Entrepr.	AK7	0.00	0.00	0.02	0.04	0.16
Maintenance	AK8	0.05	0.00	0.00	0.06	0.00
Marketing	AK9	0.00	0.00	0.04	0.06	0.05
Product Design	AK10	0.04	0.05	0.00	0.03	0.05
Production Management	AK11	0.25	0.20	0.11	0.06	0.00
Project Management	AK12	0.05	0.00	0.00	0.00	0.00
Quality	AK13	0.10	0.07	0.00	0.04	0.05
Research Methods	AK14	0.05	0.07	0.06	0.05	0.00
Sociology and Law	AK15	0.05	0.00	0.00	0.06	0.00
Supply Chain Management	AK16	0.03	0.07	0.25	0.06	0.05
Sustainability	AK17	0.00	0.07	0.00	0.00	0.15
Systems Design	AK18	0.00	0.04	0.03	0.06	0.15
Others	AK19	0.00	0.00	0.00	0.00	0.00

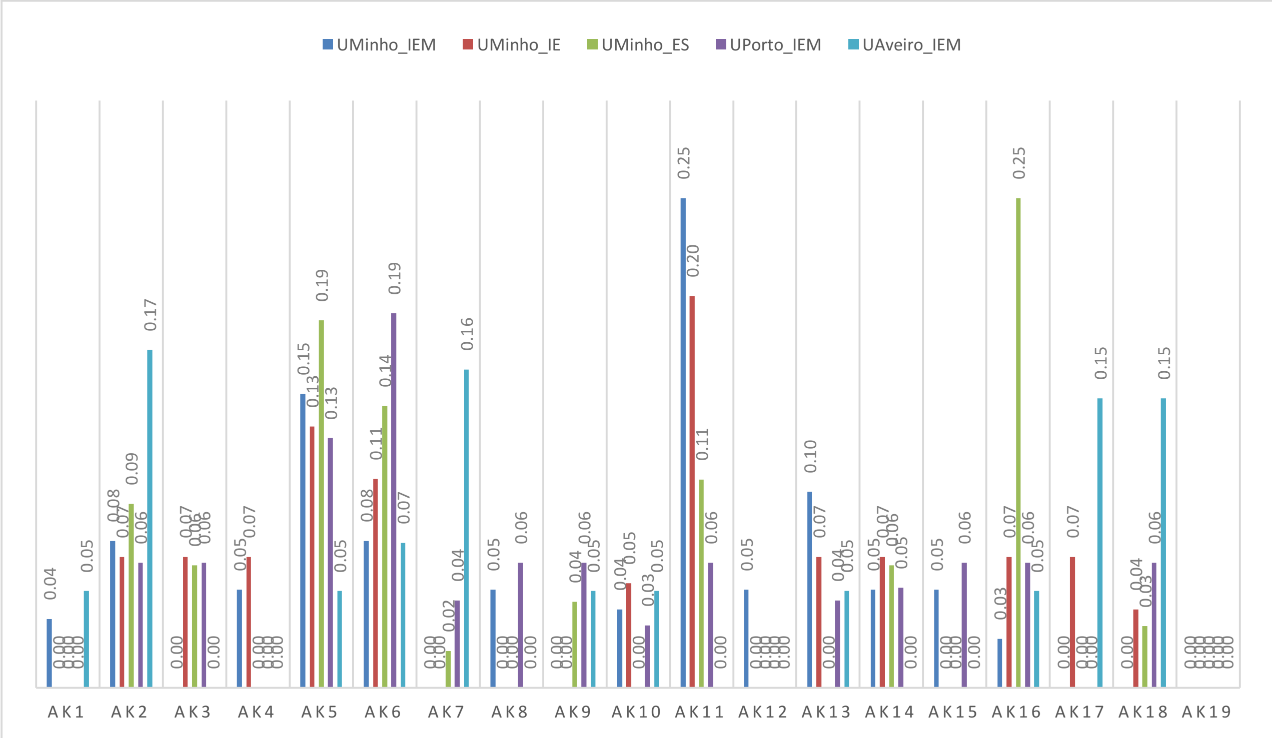

Figure 12. Areas of Knowledge Graph – Results from Portugal selected programs

3.2.3 Romania – selected programs

Four programs from Romania were analysed and the summary of results are presented in the Table 8 / Figure 13. Three of these programs are from UPB - University Politehnica of Bucharest and another from UGhAIasi – "Gheorghe Asachi" Technical University of Iasi.

All programs at UPB (UPB_IE, UPB_DIPI and UPB_IPFP) presents a focus on Research Methods with more than 12%. These courses are related to the final thesis and, for that reason, this area is common in the programs offered by the university. Nevertheless, the programs have different focus in other areas of knowledge. For instance, 13% of the UPB_IE curricula focus on Automation. The other two programs present strong emphasis indicators, regarding Product Design (UPB_DIPI 30% and UPB_IPFP 18%). Both these programs offer courses in Foreign Languages (English and French) that were included in the category "Others".

The area of knowledge that stands out from UGhAIasi program is Systems Design covering 15% of the curricula. Courses related to Sociology and Law are also relevant in the program with a weight of 13%. Moreover, courses classified as belonging to the areas of knowledge category "Others" (9%) emerged from the analysis, namely "Elements of Technological Physics" and "Special Cold Forming Technologies".

Table 8. Areas of Knowledge Results – Romania

Area of Knowledge	AREA CODE	UPB_IE	UPB_DIPI	UPB_IPFP	UGhAIasi
Automation	AK1	0.13	0.11	0.10	0.07
Comp. and Inf. Systems	AK2	0.00	0.00	0.03	0.03
Economics Engineering	AK3	0.00	0.03	0.03	0.03
Ergonomics and Human Factors	AK4	0.00	0.06	0.00	0.02
IEM	AK5	0.25	0.12	0.15	0.13
Industrial Optimization	AK6	0.06	0.00	0.00	0.05
Innovation and Entrepr.	AK7	0.09	0.06	0.03	0.06
Maintenance	AK8	0.00	0.00	0.00	0.03
Marketing	AK9	0.06	0.00	0.03	0.00
Product Design	AK10	0.06	0.30	0.18	0.03
Production Management	AK11	0.06	0.08	0.10	0.06
Project Management	AK12	0.00	0.00	0.03	0.03
Quality	AK13	0.00	0.00	0.05	0.03
Research Methods	AK14	0.19	0.12	0.15	0.06
Sociology and Law	AK15	0.03	0.00	0.00	0.13
Supply Chain Management	AK16	0.00	0.00	0.00	0.00
Sustainability	AK17	0.00	0.00	0.00	0.00
Systems Design	AK18	0.06	0.06	0.03	0.15
Others	AK19	0.00	0.06	0.10	0.09

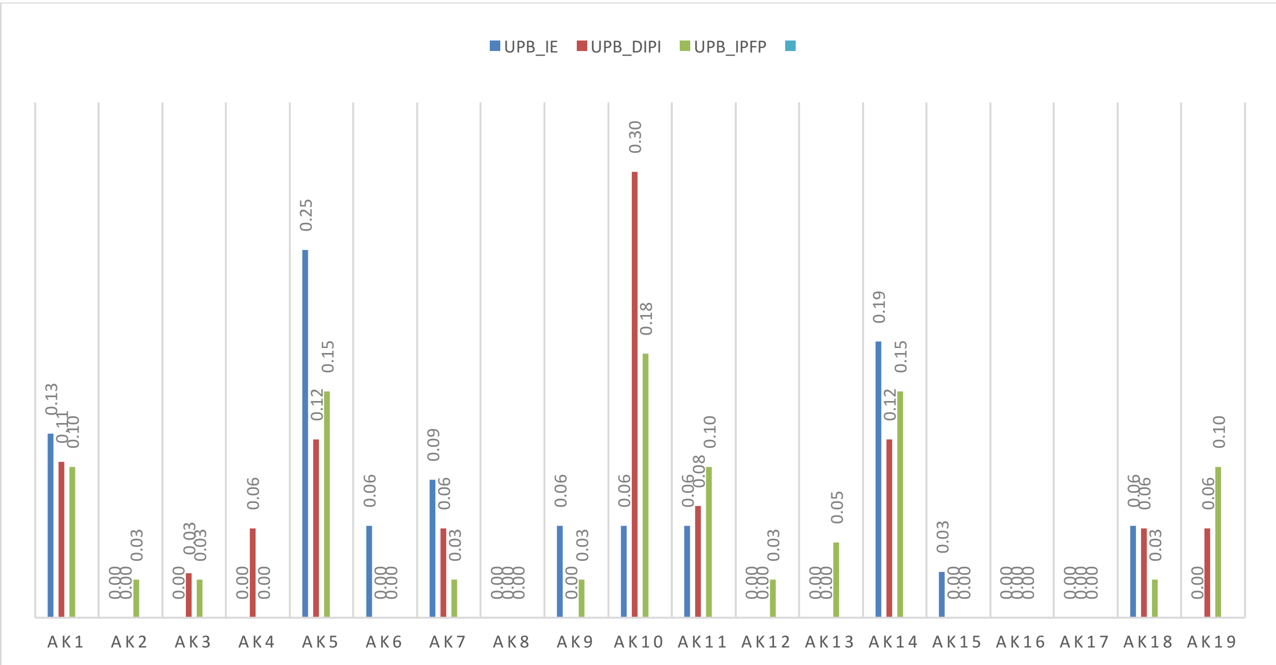

Figure 13. Areas of Knowledge Graph – Results from Romania selected programs

3.2.4 Europe – other selected programs

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.

The results of the analysis are presented in the Table 9 / Figure 14 and it is possible to identify some similarities and differences between them.

The programs from IPG and UPM presents the same focus – Systems Design. In regard of IPG, this are covered in 15% of the curricula and for UPM is even more - 34%. Product Design also show similar results of 11% at IPG and 12% at UPM. However, the IPG program shows two more areas with a similar weight, specifically Industrial Optimization (12%) and Sustainability (11%).

The focus at UG is different in terms of predominance of areas of knowledge. In this case, 20% of the program is related to Economics Engineering. The areas Production Management and Supply Chain Management have both a weight of 11%.

Table 9. Areas of Knowledge Results – programs selected from other European countries

Area of Knowledge	AREA CODE	IPG	UG	UPM
Automation	AK1	0.00	0.00	0.13
Comp. and Inf. Systems	AK2	0.07	0.00	0.04
Economics Engineering	AK3	0.10	0.20	0.04
Ergonomics and Human Factors	AK4	0.00	0.00	0.09
IEM	AK5	0.03	0.21	0.02
Industrial Optimization	AK6	0.12	0.00	0.00
Innovation and Entrepr.	AK7	0.03	0.04	0.03
Maintenance	AK8	0.00	0.00	0.00
Marketing	AK9	0.01	0.02	0.00
Product Design	AK10	0.11	0.00	0.12
Production Management	AK11	0.10	0.11	0.00
Project Management	AK12	0.00	0.07	0.08
Quality	AK13	0.03	0.07	0.00
Research Methods	AK14	0.03	0.07	0.00
Sociology and Law	AK15	0.01	0.03	0.00
Supply Chain Management	AK16	0.07	0.11	0.03
Sustainability	AK17	0.11	0.00	0.03
Systems Design	AK18	0.15	0.07	0.34
Others	AK19	0.03	0.00	0.04

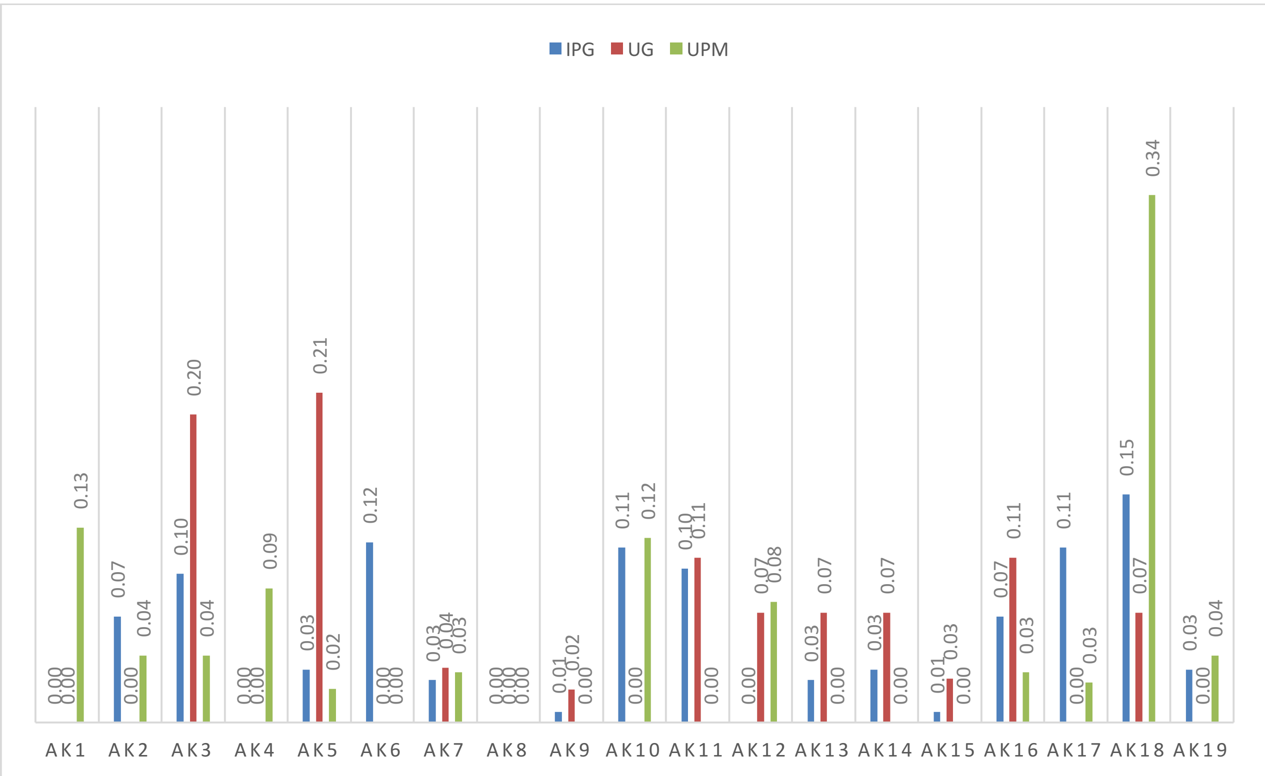

Figure 14. Areas of Knowledge Graph – results from other European selected programs

3.2.5 Europe – selected programs overall perspective

An overview of the predominance of areas of knowledge in the 14 European programs is provided in this section. The main results are presented in Table 10 / Figure 15 in which is possible to confirm the emphasis of one specific area of knowledge in IE curricula: Production Management. Concerning the IEM area of knowledge, the result is similar as the Thai context, in which most of the programs presents courses classified as IEM (thesis, internship, seminars, amongst other).

However, looking at the standard deviation it is possible to identify a large variation between programs, which confirms the general profile of the Industrial Engineering area. Particularly in some areas of knowledge, the standard deviation is higher, which shows the diversity in distribution between all programs. Specifically: Automation, Ergonomics and Human Factors, Maintenance, Project Management, Sociology and Law, Supply Chain Management, Sustainability and Others. It is important to mention that most of the courses related to the category "Others" focus on Foreign Languages.

With this in mind, the results show the diversity of areas of knowledge in Industrial Engineering context and, consequently, the diversity of the programs in which is possible to identify common issues and differences.

Table 10. Areas of Knowledge – European selected programs overall perspective

Area of Knowledge	AREA CODE	EUROPEAN PROGRAMS	EUROPEAN PROGRAMS STDV
Automation	AK1	0.04	0.05
Comp. and Inf. Systems	AK2	0.06	0.04
Economics Engineering	AK3	0.05	0.05
Ergonomics and Human Factors	AK4	0.02	0.03
IEM	AK5	0.12	0.07
Industrial Optimization	AK6	0.07	0.06
Innovation and Entrepr.	AK7	0.05	0.04
Maintenance	AK8	0.01	0.02
Marketing	AK9	0.02	0.02
Product Design	AK10	0.08	0.08
Production Management	AK11	0.11	0.08
Project Management	AK12	0.02	0.03
Quality	AK13	0.03	0.03
Research Methods	AK14	0.07	0.05
Sociology and Law	AK15	0.04	0.05
Supply Chain Management	AK16	0.05	0.07
Sustainability	AK17	0.03	0.05
Systems Design	AK18	0.09	0.08
Others	AK19	0.03	0.04

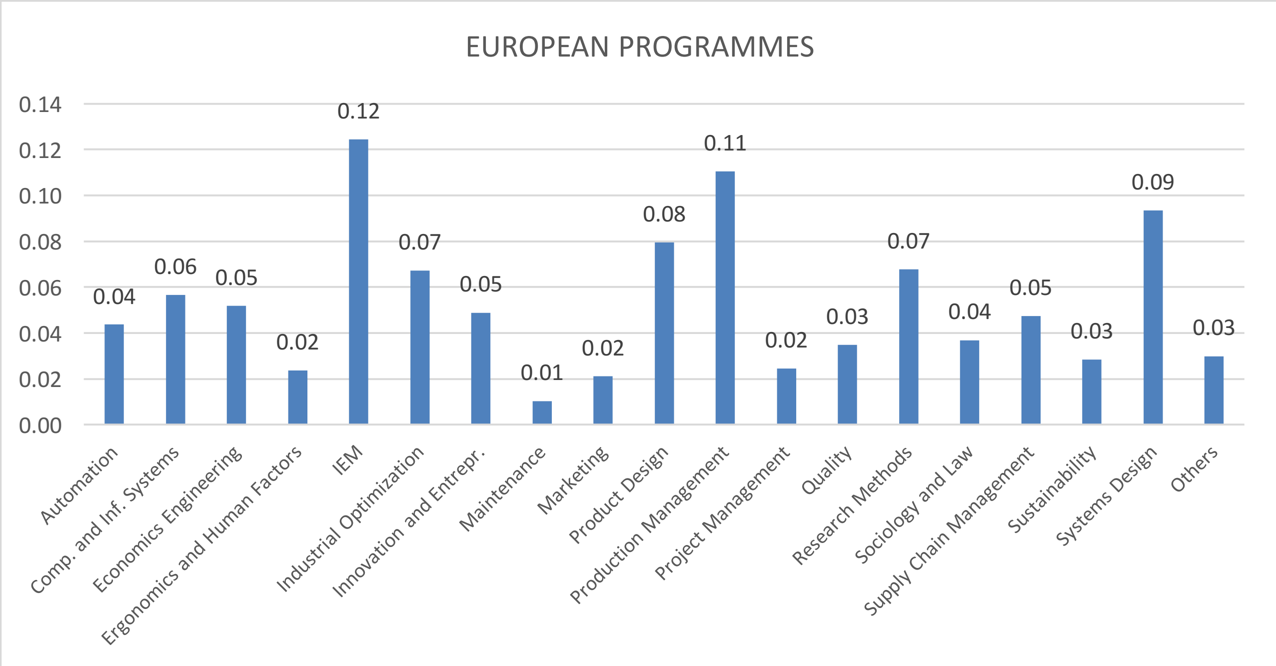

Figure 15. Areas of Knowledge Graph – European selected programs overall perspective

4 Results – Competences' analysis

The results related to the development of competences in MSIE programs are related to the learning outcomes (LO) each course aims developing in the students. As explained in the section *Framework for Analysis* integrated in the methodology of the study, the learning outcomes of each course have been qualitatively classified in relation to the predefined framework of technical and transversal competences:

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

As each course usually refer between three to six LOs, these classifications of competences are weighted in relation to the number of LOs in each course. Thus, for each course the sum of weights of competences will sum up to 1.0. The project participants collected learning outcomes of courses of industrial engineering and related programs, mainly in their own universities. Other universities were added to the study in order to create a larger database of analysis. The universities and programs were already mentioned in the study about areas of knowledge. Nevertheless, one important issue should be mentioned that would influence the main recommendations for curriculum design: several universities, both from European countries and from 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, 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 one program presented a comprehensive list of learning outcomes useful for the analyses, the AIT program. For the European part, it was possible to collect and analyse information about courses' learning outcomes of nine programs.

4.1 Learning Outcomes – Thailand

The analysis of formal curriculum allowed the identification of a lack of information regarding learning outcomes in most programs from Thailand because this is not required for certification of programs. Thus, only the program from AIT partner presented suitable information that was analysed using a classification scheme previously described.

One of the main results arising from the analysis of the AIT program is that it does not present references to transversal competences (coded as TRC# in Table 11 / Figure 16). As a known result in higher education, teachers rarely give a high importance to these type of competences (Mesquita et al., 2015). Even though these are highly valued by companies for Industrial Engineering professional activities (Lima, Dinis-Carvalho, Sousa, Arezes, & Mesquita, 2017; Lima, Mesquita, Rocha, & Rabelo, 2017). Moreover, at AIT the installed institutional culture is not to define transversal competences, which reinforces the known results from other studies. The technical competence with the higher number of references is "TC5 - Developing projects, implementing systems, applying methods and procedures" with 0.42 weight. As an example of a LO classified as TC5 is "Apply different depreciation and taxation methods" in the course "Engineering Economy". After this, it is possible to identify a set of technical competences with similar weights TC1, TC2, and TC7. TC7 is mainly related to acquiring knowledge and being able to relate and compare it. TC1 and TC2 are related to the ability to analyse and design production (sub) systems, processes and products, which are high level of competences in relation to the Bloom taxonomy (Bloom, 1979; Bloom & Krathwohl, 1956; Krathwohl, 2002).

Table 11. Learning Outcomes Results – Thailand Partner Universities - AIT program

CODE	DESCRIPTION	AIT
TC1	Production systems analysis and diagnosis	0.17
TC2	Production systems design / Production Planning and Control processes design	0.19
TC3	Planning production and project processes	0.00
TC4	Monitoring and Controlling processes and production system performance	0.00
TC5	Developing projects, implementing systems, applying methods and procedures	0.42
TC6	Evaluating production systems and processes	0.02
TC7	Describing, comparing and selecting technologies, methods and paradigms	0.21
TC8	Articulating knowledge objects from various areas	0.00
TRC1	Communication competences	0.00
TRC2	Ability to deal with the unexpected / Working in environments of uncertainty	0.00
TRC3	Teamwork competences	0.00
TRC4	Ability to solve problems	0.00
TRC5	Leadership competences	0.00
TRC6	Innovation / Creativity	0.00
TRC7	Planning and organization competences	0.00
TRC8	Professional ethic	0.00
TRC9	Ability to making decisions	0.00
TRC10	Foreign languages knowledge	0.00
TRC11	Entrepreneurship	0.00

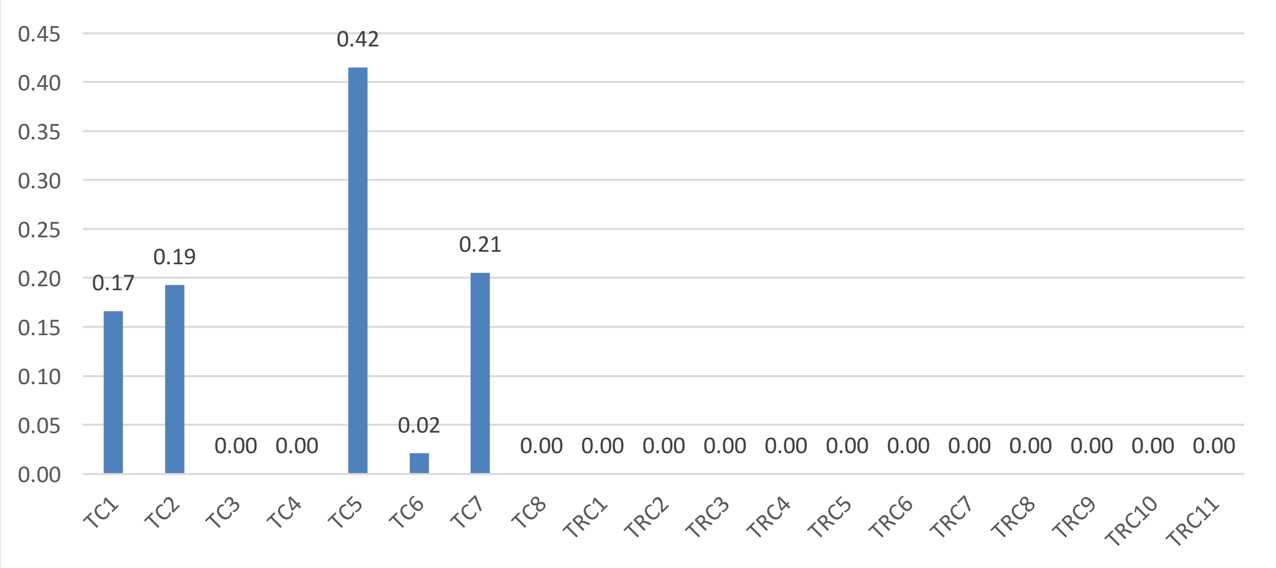

Figure 16. Learning Outcomes Graph – Thailand Partner Universities - AIT program

4.2 Learning Outcomes – Europe

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

4.2.1 Poland

Two master programs from Poland were analysed, one from CUT (Częstochowa University of Technology) and the other from AGH (University of Science and Technology). For both institutions, the main weight of type of competences is related to what it could be referred as a "knowledge" based type competence "TC7 - Describing, comparing and selecting technologies, methods and paradigms". After this, there are also important references to TC5, related to the application of knowledge. Finally, a few references are related to Production Systems Design, related to design of systems, processes or products.

As usual, a considerable low number of references to some transversal competences can be found, related to teamwork and communication. A special emphasis in foreign languages can be found in the AGH program, which denotes a specificity of their graduate profiles

Table 12. Learning Outcomes Results – Poland selected programs

CODE	DESCRIPTION	CUT_MPE	AGH_MPE
TC1	Production systems analysis and diagnosis	0.04	0.02
TC2	Production systems design / Production Planning and Control processes design	0.09	0.01
TC3	Planning production and project processes	0.01	0.01
TC4	Monitoring and Controlling processes and production system performance	0.00	0.00
TC5	Developing projects, implementing systems, applying methods and procedures	0.16	0.32
TC6	Evaluating production systems and processes	0.02	0.01
TC7	Describing, comparing and selecting technologies, methods and paradigms	0.53	0.43
TC8	Articulating knowledge objects from various areas	0.03	0.00
TRC1	Communication competences	0.07	0.04
TRC2	Ability to deal with the unexpected / Working in environments of uncertainty	0.00	0.00
TRC3	Teamwork competences	0.03	0.01
TRC4	Ability to solve problems	0.00	0.03
TRC5	Leadership competences	0.01	0.00
TRC6	Innovation / Creativity	0.00	0.00
TRC7	Planning and organization competences	0.00	0.01
TRC8	Professional ethic	0.00	0.00
TRC9	Ability to making decisions	0.00	0.00
TRC10	Foreign languages knowledge	0.00	0.12
TRC11	Entrepreneurship	0.00	0.00

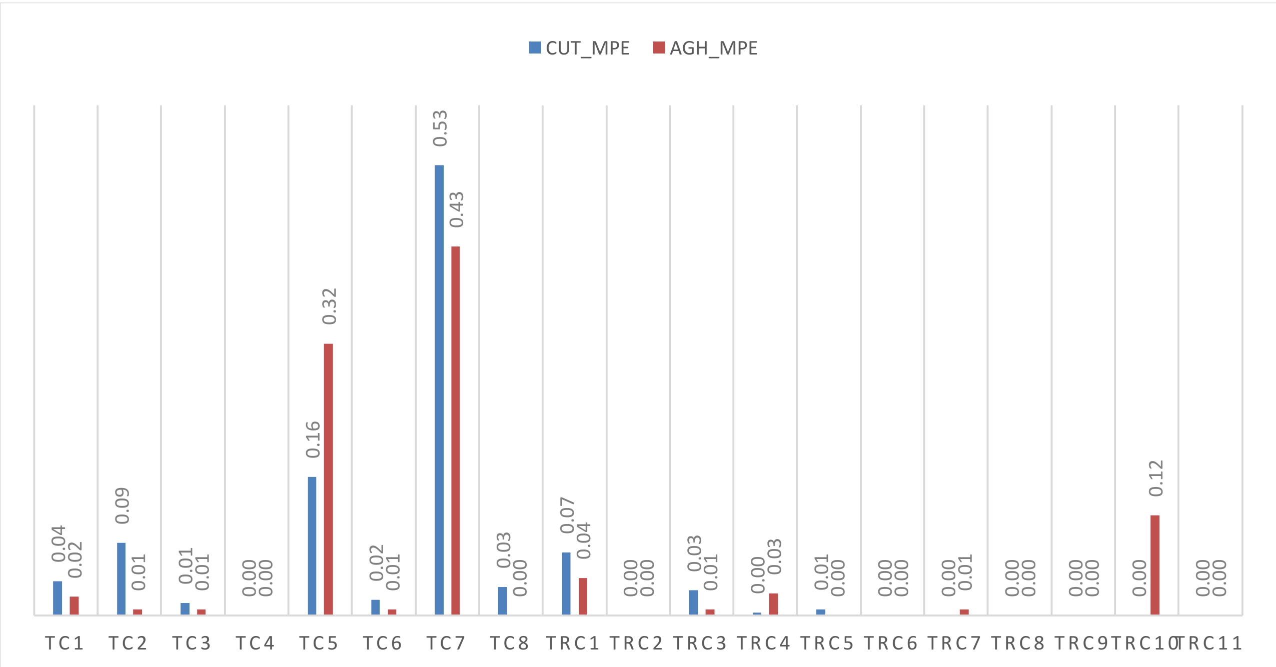

Figure 17. Learning Outcomes Graph – Poland selected programs

4.2.2 Portugal

In Portugal, it was possible to collect information from five different Industrial Engineering related programs, from three universities: UMinho – University of Minho; UPorto – University of Porto; UAveiro – University of Aveiro. The result of the analysis is summarised in Table 13 / Figure 18. It can be noted that UAveiro, UPorto and UMinho_ES have a higher number of references to TC7, while UMinho_IEM and UMinho_IE have a higher number of references to TC5. All programs are essentially similar regarding the following LO referenced, TC2 (design) and TC1 (analysis). It was possible to find some references to the articulation of different areas of knowledge in UMinho_IEM and UMinho_ES programs.

Regarding transversal competences, as usual, there are a much lesser number of references than for technical competences. Nevertheless, the programs from UMinho present more references to these type of competences, being communication the most referred, followed by teamwork competences.

Table 13. Learning Outcomes Results – Portugal selected programs

CODE	DESCRIPTION	UMinho_IEM	UMinho_IE	UMinho_ES	UPorto_IEM	UAveiro_IEM
TC1	Production systems analysis and diagnosis	0.06	0.07	0.09	0.10	0.01
TC2	Production systems design / Production Planning and Control processes design	0.13	0.18	0.19	0.17	0.16
TC3	Planning production and project processes	0.07	0.00	0.02	0.02	0.00
TC4	Monitoring and Controlling processes and production system performance	0.01	0.02	0.03	0.01	0.00
TC5	Developing projects, implementing systems, applying methods and procedures	0.31	0.36	0.15	0.21	0.21
TC6	Evaluating production systems and processes	0.04	0.01	0.04	0.02	0.02
TC7	Describing, comparing and selecting technologies, methods and paradigms	0.18	0.29	0.32	0.41	0.55
TC8	Articulating knowledge objects from various areas	0.04	0.01	0.07	0.00	0.00
TRC1	Communication competences	0.10	0.04	0.05	0.02	0.00
TRC2	Ability to deal with the unexpected / Working in environments of uncertainty	0.00	0.00	0.00	0.00	0.00
TRC3	Teamwork competences	0.04	0.01	0.02	0.01	0.00
TRC4	Ability to solve problems	0.02	0.00	0.01	0.00	0.00
TRC5	Leadership competences	0.00	0.00	0.00	0.00	0.02
TRC6	Innovation / Creativity	0.00	0.00	0.00	0.00	0.01
TRC7	Planning and organization competences	0.00	0.00	0.00	0.00	0.00
TRC8	Professional ethic	0.00	0.00	0.00	0.00	0.00
TRC9	Ability to making decisions	0.00	0.00	0.00	0.00	0.00
TRC10	Foreign languages knowledge	0.01	0.00	0.00	0.00	0.00
TRC11	Entrepreneurship	0.00	0.00	0.00	0.00	0.00

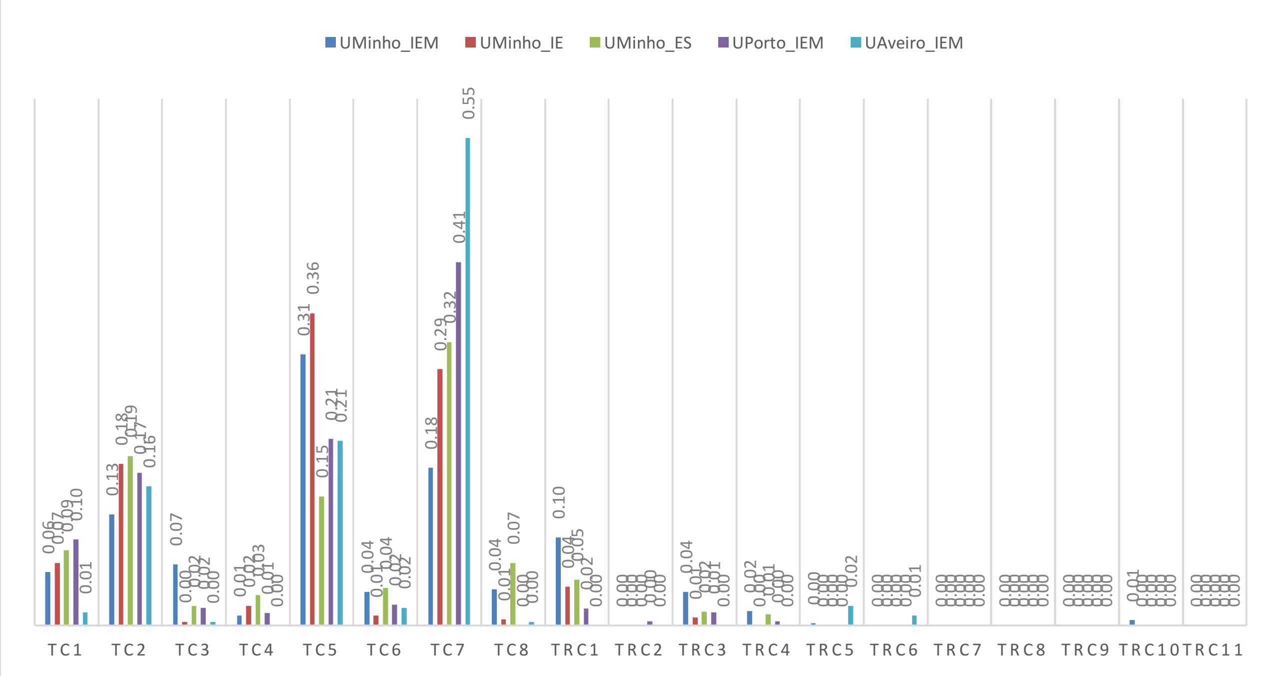

Figure 18. Learning Outcomes Graph – Portugal selected programs

4.2.3 Programs from other European countries

Considering the three programs that were analysed in regard to areas of knowledge, it was possible to analyse two of them (Table 14 and Figure 19), one from the IPG - Institut Polytechnique de Grenoble and the other from the UG - University of Greenwich. A similar pattern of emphasis in types of competences was identified, due to the importance of technical competences derived from TC7, TC5, TC2 and TC1. A lesser weight is given to transversal competences, being communication and ethics the most important for UG, and leadership for IPG.

Table 14. Learning Outcomes Results – Other European selected programs

CODE	DESCRIPTION	IPG	UG
TC1	Production systems analysis and diagnosis	0.01	0.04
TC2	Production systems design / Production Planning and Control processes design	0.17	0.12
TC3	Planning production and project processes	0.01	0.00
TC4	Monitoring and Controlling processes and production system performance	0.00	0.00
TC5	Developing projects, implementing systems, applying methods and procedures	0.29	0.16
TC6	Evaluating production systems and processes	0.01	0.04
TC7	Describing, comparing and selecting technologies, methods and paradigms	0.40	0.48
TC8	Articulating knowledge objects from various areas	0.01	0.01
TRC1	Communication competences	0.01	0.05
TRC2	Ability to deal with the unexpected / Working in environments of uncertainty	0.00	0.00
TRC3	Teamwork competences	0.00	0.00
TRC4	Ability to solve problems	0.01	0.00
TRC5	Leadership competences	0.05	0.02
TRC6	Innovation / Creativity	0.01	0.00
TRC7	Planning and organization competences	0.01	0.00
TRC8	Professional ethic	0.00	0.05
TRC9	Ability to making decisions	0.00	0.00
TRC10	Foreign languages knowledge	0.00	0.01
TRC11	Entrepreneurship	0.01	0.00

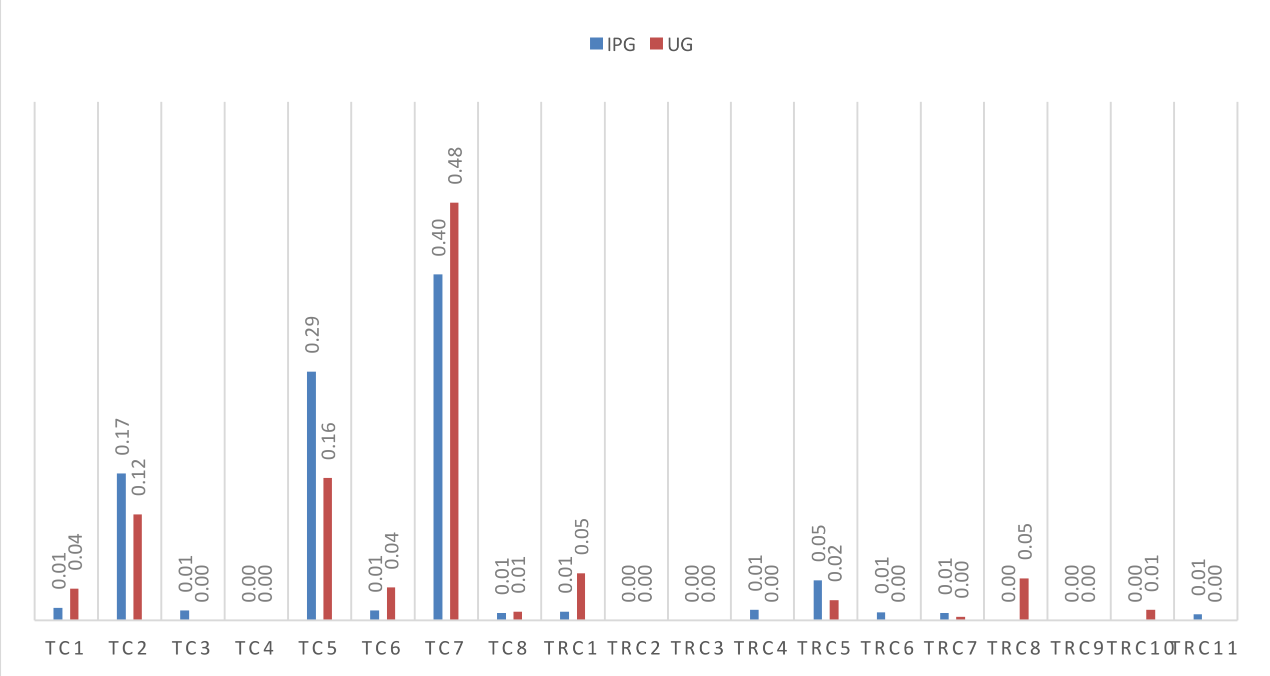

Figure 19. Learning Outcomes Graph – Other European selected programs

4.2.4 Selected European programs - overall perspective

The integrated perspective of all selected European programs is presented in Table 15 and Figure 20. These figures represent the average of all selected European programs. 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 15. Learning Outcomes Results – Selected European programs overall perspective

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

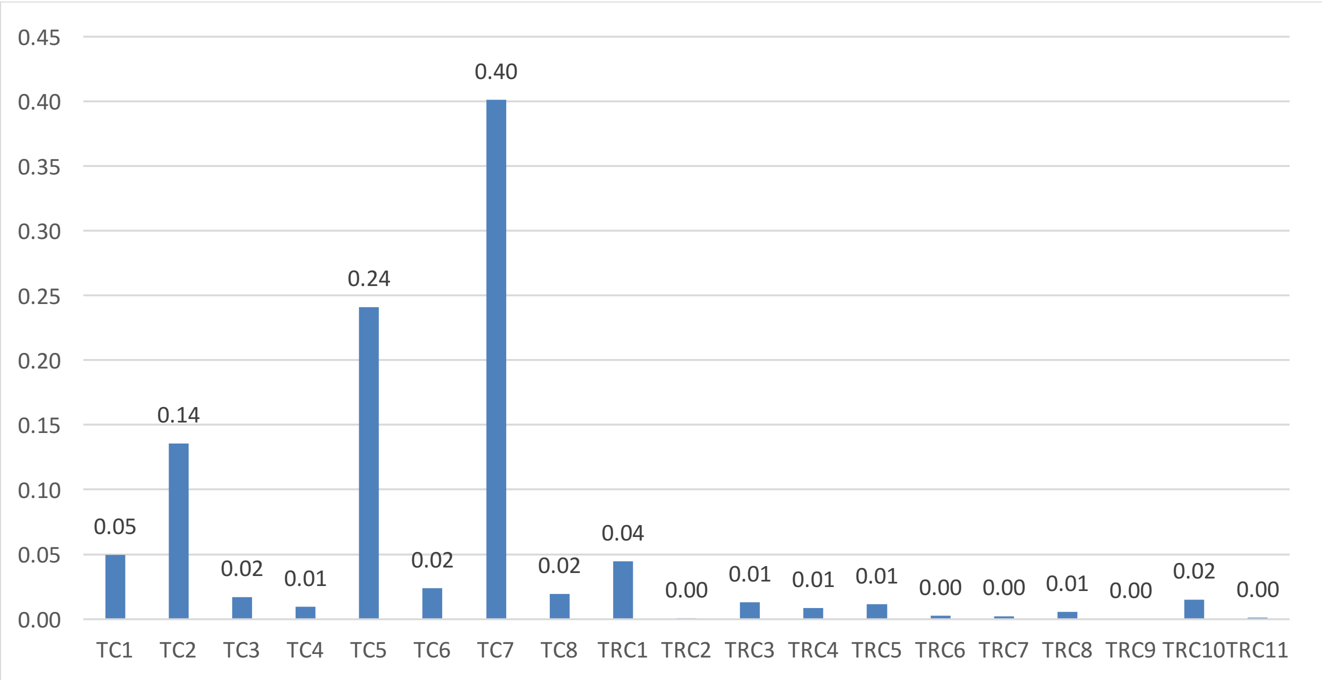

Figure 20. Learning Outcomes Graph – Selected European programs overall perspective

5 Discussion and Recommendations

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 competences. For that reason, the data collection intended to get 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 (9 for AIT) courses, corresponding of 18 to 24 (26 for AIT) hours of course work. The thesis work will vary from 12 to 22 credits between 2 or 3 semesters. In Portugal and Romania, the master courses will 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 will have 90 ECTS (European credit transfer system) in 1.5 years, after a 3.5 year-bachelor. In all cases, the thesis work will be developed during one or two semesters.

A comprehensive analysis of selected Industrial Engineering and related master degrees curricula was made. This analysis was based in the analysis of the formal curriculum, using information collected from documents. This information allowed to create a perspective on the main areas of knowledge developed in each program and the main type 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 modes 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 four to five courses per semester in the first year.

Recommendation 1: The structure of the master program should have two 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 26 selected programs have an explicit result regarding a 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 type of activities. Additionally, it was clear that most of the Thai master programs have a strong emphasis in optimization, and European programs have higher emphasis on production management and production systems design. Nevertheless, all selected programs from Thailand and European countries have a common focus 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 create 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 would allow for different in depths developments of areas of knowledge. As an example, Problem and Project-Based Learning (PBL) courses can make the curriculum more flexible, because it 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 for each course. Considering that competences are one 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 the MSIE4.0 project define learning outcomes for each course. The number of LOs should allow a clear understanding of the *DNA* of a course and, additionally, should help the student to understand what is expected from him/her and, in somehow, how he/she will be assessed. There is not a magical number, but usually a number between four and eight can be found in course descriptions in 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 it is what makes 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 be developing in their degrees. Thus, the following recommendation is that MSIE4.0 give the 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 is a part of Task 1.2 and give 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.

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