WP 1 - Gap Analysis

Outcome 1.7 - Recommendations for specifications and areas of specialization for the curriculum

Project Acronym:	MSIE 4.0
Project full title:	Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry
Project No.:	586137-EPP-I-2017-I-TH-EPPKA2-CBHE-JP
Funding Scheme:	Erasmus + KA2 - Capacity Building in the field of Higher Education
Coordinator:	AIT
Work Package:	WP1 – Gap Analysis
WP Leaders:	Rui M. Lima (UMinho) and Wichai Chattinnawat (CMU)
Task Title:	Task 1.6 Developing recommendations for the specifications and areas of specialization for the curriculum
Task Leader:	Rui M. Lima (UMinho)
Last version date:	22/02/2019
Status:	Final
Dissemination Level:	Institution -Local - National -International

REVISION SHEET

Version	Date	Author (Partner/Person)	The revision reason
1	20/02/2019	UMinho / Rui M. Lima	First version - draft version of WP1 Task1.6 - Outcome 1.7. Include contributions from CUT, UPB and AIT.
2	22/02/2019	UMinho / Rui M. Lima	Second version – final version of WP1 Task1.6 - Outcome 1.7, reviewed after WP1 feedback. Sent for QCMB evaluation.

DISTRIBUTION LIST

Project Partner	Acronym	Responsible (for dissemination)
University of Minho	UMinho	Rui Lima
Chiang Mai University	CMU	Wichai Chattinnawat
Asian Institute of Technology	AIT	Huynh Trung Luong
King Mongkut's University of Technology North Bangkok	KMUTNB	Athakorn Kengpol
Thammasat University	TU	Samerjit Homrossukon
Khon Kaen University	KKU	Sirorat Pattanapairoj
Prince of Songkla University	PSU	Supapan Chaiprapat
University Politehnica of Bucharest	UPB	Tom Savu
Częstochowa University of Technology	CUT	Dorota Jelonek

Table of Contents

1 Executive Summary

WP1 aims to provide a comparative analysis of the actual situation concerning the MSc curricula in Industrial Engineering offered in Thai and EU partner countries universities, the identification of the gaps between the real needs of the industry, the student needs and the actually offered curricula. Based on a wide analysis of the target group needs, the identified gaps and on world trends and developments in Industrial Engineering, the factors that will provide a competitive advantage to the curriculum were identified and presented in the previous outcome. These competitive factors were analysed and transformed in specific recommendations for the curriculum in this report. The main recommendations is to develop a curriculum supporting sustainable smart industries characterized by smart production and co-created product design & development, enhanced with big data and real-time data. MSIE4.0 will mainly support industries with the development of both technical and transversal competences through active learning, experiential learning, and problem and project-based approaches involving industries. Additionally, the curriculum should be able to personalise the offer, supporting different profiles of students through thematic learning and flexible learning formats. Finally, this outcome also present target curricular specifications aiming to support the development of an integrated and uniform two-year curriculum, characterised by program and course learning outcomes.

2 Introduction

The most important outcomes of WP1 will be reports with the main conclusions concerning the gap analysis, the identification of competitive factors and the recommendations for developing a proposed curriculum for a Master in Industrial Engineering aligned with the Industry 4.0 needs.

Task 1.6 is the final activity of WP1 intending to provide a recommendation to WP2 and WP3 for next phase of the project on curriculum development. The main inputs for this task came from the result of the prior task, which in this case is the competitive factors for the curriculum (Outcome 1.6).

"Personalizing Your Learning Experience to Support Sustainable Smart Industry" is the summary from the Outcome 1.6. This MSIE 4.0 curriculum will focus on building both technical and transversal competences for graduates with thematic active learning activities, especially those immersing students into practical, real-world problems. For technical competences, the priority will be on smart production and on smart products and co-create design, with a focus on big data and real-time data/sensors. Last but not least, the curriculum will be developed with a modular concept to provide flexibility to different groups of students.

3 Recommendations for specifications

This section summarizes the mains recommendations for developing the MSIE4.0 curriculum proposal, which are based on a few target curricular specifications and inspired by the competitive factors in the way represented by Figure 1.

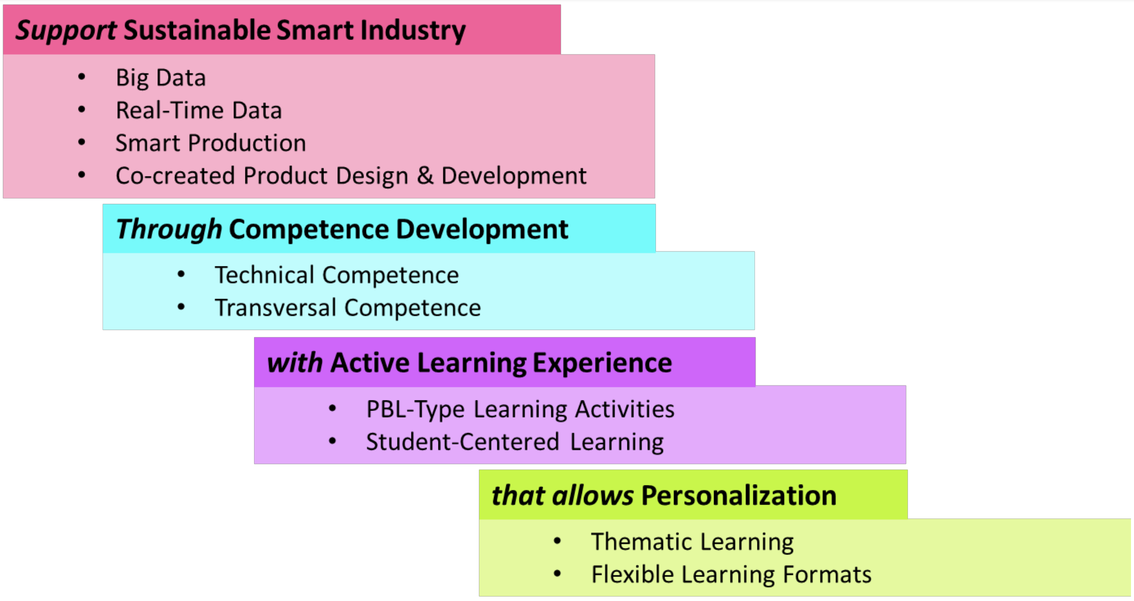

Figure 1. Summary of recommendations for MSIE4.0 curriculum

3.1 Support Sustainable Smart Industry

Progress towards gap analysis within WP1 has led to identifying smart products, smart factory, smart operations and data driven services as a key features of MSIE4.0 approach to Industry 4.0 concept. These features have been considered from the point of view of MSIE student competence building within domain specific supporting technologies and areas of application. The main application areas that should be supported by MSc in IE curricula are advanced manufacturing processes, smart production concept and co-created product design and development. The technologies that could enhance the development within these domains of application in the most efficient manner, according to industry needs analysis, are big data, real time data with sensor and mobile. Therefore, with the contribution of teams' insights, the competitive factors for the MSIE4.0 curriculum are identified as:

- Supporting smart production concept,
- Supporting co-created product design and development concept,
- Supporting advanced manufacturing processes,

These competitive factors are closely linked with the industry needs as:

- Competences in big data,
- Competences in real time data and sensors,
- Competences in mobile application.

In order to transform these competitive factors into recommendations on specifications of MSIE curriculum and proposals on the areas of its specialization it is necessary to give a proper background on curriculum specific recommendations. These type of recommendations could be formulated as program and course learning outcomes, types of courses and their contents, number of course hours and their structure, leading topics and areas of specialization, learning and teaching methods, internal and external stakeholder involvement in the educational process and coherence and integrity of curriculum. These are certainly not all the factors important in curriculum development but they certainly should be addressed with issues on technology and its application areas.

Technology specific integrative approach in curriculum is not enough for Industry 4.0 challenges. The integration should also refer to economic and market aspects of business. Therefore, the recommendation is to provide students with appropriate knowledge, competences and skills that would enable them to assess the economics of technological breakthrough of products, processes and solutions. This skill set should be built upon both technical and transversal competences required within IE field. The curriculum should provide specific courses but also opportunities within more technology oriented courses to use and develop competences on economic analysis and feasibility studies, market research, marketing and sales, entrepreneurship and finance. These competences should gain IE, and specifically, Industry 4.0 context, through their integration within curriculum.

The important outcome of WP1 gap analysis is also the valuation of technologies and their application areas and their potential importance for MSIE curriculum development. It is crucial in defining the PLOs and course structure of MSIE curriculum, enabling the purposeful division of PLOs, course workload and related course specific learning outcomes. The recommendation is to use that valuation directly as a measure for curriculum structure. Since, the number of PLOs and course hours are clearly defined for MSc type of studies, the valuation and significance of technologies and their application areas could be also used as cut-off frontier for topic selective approach to curriculum development. This is also the case for areas of specialization that could have been defined on technology / area of application nexus. Figure 2 shows the matrix of technologies and their possible application areas with IE related valuation. Possible outcomes within red marked area should be regarded as a key source in defining PLOs, building course structure and learning and teaching methods coupling.

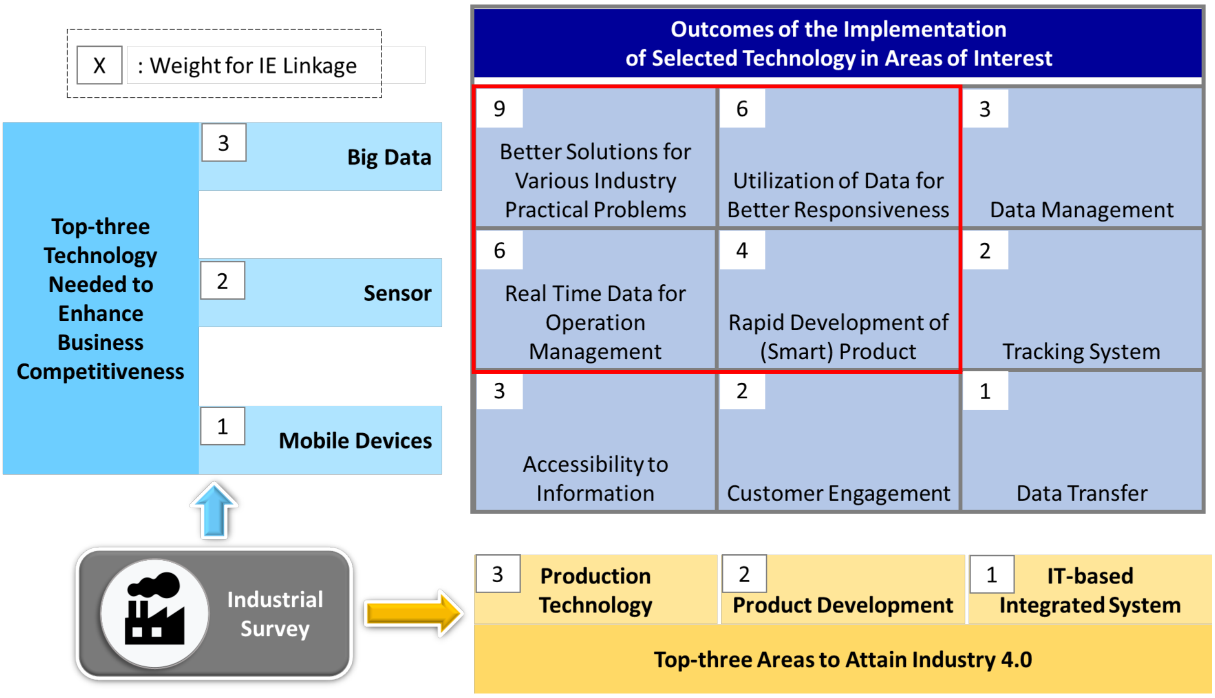

Figure 2. Valuation of technologies and application areas

The expectations of smart and sustainable industry towards MSIE graduates are certainly on high applicability of their knowledge and competences. It is very true for technology and their application areas and it implies strong orientation on practical issues within MSIE curriculum. This could be only achieved with well-equipped laboratories and project and problem oriented approaches within the course of the MSIE studies. This could be also achieved through building and exploiting strong partnership with industry and its active participation in providing both content and space for training. Curriculum development and implementation process should be realized with active and meaningful engagement of industrial partners. This process should be regarded as continuous process based on flexible and thematic approaches to the curriculum that would enable inputs from industry. Curriculum implementation should be partially based on industry driven tasks and projects and use of industry related training ground.

3.2 Competence development

Technical competences are the core competences of a professional activity, and it is 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, global Higher Education systems have 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 needs the implementation of specific educational strategies to be effective, and this should be considered in the curriculum development.

Taking into account the curriculum and teaching methods analysis, employers' needs, the students' needs, and global Higher Education frameworks like the ABET norms explained in GD-T1.3_O1.4 or the European Qualifications Framework - EQF, it is **recommended that the expected graduates' competences are formulated as learning outcomes for the program as a whole and also for each course of the program**.

The formulation of learning outcomes should take into account a few basic principles:

1. Competences should be formulated into two broad categories: **Technical** (or core) competences and **transversal** competences.
2. Competences should be formulated by harmonizing three categories of outcomes: Knowledge, skills (abilities), and attitudes (e.g., responsibility and autonomy).
3. The degree of depth of the two categories mentioned in point 1 must correspond to the master level of complexity. An example of the description of this level of complexity is presented in the EQF.

3.3 Active Learning Experience

Active Learning is related to all learning environments and approaches that create meaningful learning experiences. These learning experiences should be based on relevant experiences related to the professional practice, using adequate learning environments that give context to learning, and in that way create energy and motivation for the engagement of students. Finally, real deep learning will happen when students are able to critically analyse their own learning (Bonwell & Eison, 1991; Christie & de Graaff, 2017; Felder & Brent, 2003; Prince & Felder, 2006). The increased interest in Active Learning is related to the fact that strong evidences support the effectiveness of the application of these principles, when supporting learning processes and development of competences (Freeman et al., 2014; Prince, 2004). **Thus, the master program should be developed with Active Learning environments and approaches such that the Industry 4.0 competences can be developed in an effective way**.

Active Learning environments are based on a set of principles and implemented in a multitude of ways. One of the approaches with a higher number of references in Engineering Education is Project-Based Learning approaches. These approaches can be implemented in many different ways regarding type of objectives, typologies, areas of knowledge, team dimensions and level of interaction with companies. Nevertheless, high levels of interaction with companies, solving interdisciplinary problems may increase the cognitive complexity of the learning process, taking advantage of the nature of profession related problems.

The multitude of approaches of Problem and Project-Based Learning (PBL) demonstrates one of the characteristics of PBL: its ability to deal with open-ended problems and make the curriculum more flexible. The need for a flexible curriculum was one of the recommendations of previous outcomes, and PBL can make a contribution to this goal. **Thus, the utilization of PBL as an element of flexibilization of the curriculum, may contribute for integrating interdisciplinary areas for the development of future expected, or unforeseen, competences**.

Another emerging global trend in Engineering Education is the need to create explicit curricular links with external agents, namely with industrial companies. The European Union initiative, University-Business Cooperation (UBC) (Davey, Baaken, Muros, & Meerman, 2011) describes the need to develop graduates' competences aligned with the needs of the labour market. The interaction between master programs and external agents and industrial companies can be developed by visiting industries, invite professionals or key agents of the society to deliver seminars, integrate internships and work-based learning in the curricula, or developing projects to deal with real industrial or society problems (Lima, Dinis-Carvalho, Sousa, Arezes, & Mesquita, 2017). **A strong recommendation would be to create close connections with external agents and in particular with industrial companies. These approaches contribute for effective development of competences of the graduates, by either analysing and solving real industrial problems, or developing innovative solutions to society needs and challenges**.

3.4 Personalization

Flexible formats for thematic learning is highly recommended. Flexibility in learning is value creation in supporting equal opportunity of learning. Flexible format opens up an opportunity for many prospective students who may be at a distance or may not be able to take leave from their job duty, in entering the process without sacrifice of academic quality. Flexibility in learning includes but not limited to reconfiguring course structure to be modular, allowing students to take a similar course from partner universities and relaxing learning time and place.

Thematic learning will ease student learning by connecting several fragmented subjects covered under a curriculum together with a common theme. This way of learning not only avoids the isolation of subjects or even down to topic or subtopic levels but also allows students to see a holistic picture as well as the roles of elements and their interactions throughout the learning period. Once the students build up their understanding with the theme, they will become active learners and be able to participate more and more in learning activities.

Good preparation of thematic learning also allows a curriculum to be flexible to serve different local needs which can be varied from region to region as well as to serve different industry sectors with different specific requirements. When a curriculum equips with both thematic learning and flexibility in learning, learning will never end.

3.5 Target curricular specifications

The mission of the MSIE4.0 proposed master program subscribes to the Universities' missions and aims at developing a learning and research process that will enable the development of Industrial Engineers able to adapt to the requirements of the market economy and new specific transdisciplinary fields and qualifications of Industry 4.0. These master engineers should have a deep technical, economic and managerial knowledge, and should promote the principles of sustainable development and environmental protection, performing professional and research activities with a wide range of autonomy, trained in teamwork and prepared for lifelong learning.

The integrative approach in curriculum development should be implemented by designing it as a whole organism. With regard to technology related competences and areas of its application, the recommendation is to provide comprehensive knowledge competences and skills that would allow to develop them simultaneously within different courses and modules of educational process. That would imply the use of program learnings outcomes (PLO) as a stimulator of content development, course specific learning outcomes and learning and teaching methods selection. It would be possible to cover abovementioned technologies and their application areas within a set of PLOs related to competences, knowledge and transversal skills.

Graduates of the MSIE4.0 proposed master program must be compatible with both the national labour market and regional and international labour market requirements. Therefore, the following objectives can be recommended for the program:

1. To provide learning in accordance with the requirements of the national regulations and with the demands of regional and international labour market. In this sense, the training provided is structured in accordance with the needs of the employers and with the requirements of Industry 4.0.
2. To deepen the specialized knowledge and to develop new competences in the field of Industrial Engineering related with Industry 4.0, in accordance with the strategic development directions established at national level.
3. Harmonize the curriculum structure of the master's program with that of similar courses in the Higher Education Institutions in Europe, in such a way that, in the future, both exchanges of visiting master students and teachers may be achieved, as well as mutual recognition of diplomas by partner universities.

To design the curriculum of the Master Program it is necessary to formulate three categories of specifications:

I. Curriculum content and structure specifications;
II. Specifications regarding the conditions for carrying out the didactic activities and the endowment of the laboratories;
III. Specifications regarding the formal conditions for accreditation of the study program in accordance with the regulations of the national authorities.

I. Curriculum content and structure specifications;

1. Include 4 semesters of studies. At least two semesters with four courses each of 3 credits / hours.
2. Contain an adequate number of course hours in classrooms, laboratories, and visits to companies, in accordance to the active learning teaching and learning methods recommended above.
3. Define, for the program level and for each course, Learning Outcomes (LO) and ensure its development, in accordance with the expected competences of the graduates at the master level.
4. Ensure a logical succession of disciplines and interchangeability of optional subjects.
5. Has recommended above, ensure flexibility by organizing modules (not all dependent) on basic, intermediate and advance levels.

II. Specifications regarding the conditions for carrying out the didactic activities and the endowment of the laboratories

1. The learning environments should be equipped in accordance with the recommended active learning and PBL activities.
2. Laboratories have the necessary equipment for specific experiments related with Industry 4.0.
3. The library and computerized information system shall be appropriate to the activities of the study program.
4. There are enough resources for the operation and maintenance of all the technical facilities necessary for the study program.

III. Specifications regarding the formal conditions for accreditation of the study program in accordance with the regulations of the national authorities.

1. The Master's program must meet the curriculum conditions imposed by the national accreditation authorities.
2. The Master's program must meet the administrative and endorsement conditions imposed by the national accreditation authorities.

4 References

Bonwell, C. C., & Eison, J. A. (1991). *Active Learning: Creating Excitement in the Classroom*. Washington DC: ERIC Clearinghouse on Higher Education.

Christie, M., & de Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. *European Journal of Engineering Education, 42*(1), 5-16. doi:10.1080/03043797.2016.1254160

Davey, T., Baaken, T., Muros, V. G., & Meerman, A. (2011). *30 Best Case Studies of Good Practice in the Area of UBC within Europe*. In Todd Davey, T. Baaken, M. Deery, & V. G. Muros (Eds.), Retrieved from http://www.ub-cooperation.eu/index/casestudy

Felder, R., & Brent, R. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education, 92*(1), 7-25.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415. doi:10.1073/pnas.1319030111

Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Arezes, P. M., & Mesquita, D. (2017). Development of Competences while solving real industrial interdisciplinary problems: a successful cooperation with industry. *Production journal, 27*(spe), 1-14. doi:10.1590/0103-6513.230016

Prince, M. (2004). Does Active Learning Work? A review of the Research. *Journal of Engineering Education, 93*(3), 223-231.

Prince, M., & Felder, R. M. (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education, 95*(2), 123-138.