WP 2 - Curriculum Development I: Curriculum Structure and Courses

Outcome 2.1 - A modernized curriculum for Master's degree in Industrial Engineering

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:	WP2 – Curriculum Development I: Curriculum Structure and Courses
WP Leaders:	Tomasz Nitkiewicz (CUT) and Pisut Koomsap (AIT)
Task Title:	Task 2.1. Developing curriculum structure and academic program learning outcomes
Task Leader:	Tomasz Nitkiewicz (CUT)
Last version date:	04/05/2020
Status:	Final (before pilot testing)
Dissemination Level:	Department / Faculty - Institution - Local – Regional - National - International

REVISION SHEET

Version	Date	Author (Partner/Person)	The revision reason
1	08/04/2019	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	First version – draft version of WP2 Task 2.1 – Outcome 2.1. Include contributions from CUT, AIT and all Project partners.
2	30/09/2019	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap UPB / Tom Savu Uminho / Rui Lima	Second version – draft version of WP2 Task 2.1 – Outcome 2.1. Include contributions from CUT, AIT, comments by Tom Savu UPB and Rui Lima, Uminho, and all Project partners.
3	18/11/2019	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Third version – draft version of WP2 Task 2.1 – Outcome 2.1. Include contributions from WP2 Task 2.1 team members
4	13/01/2020	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Fourth version – draft version of WP2 Task 2.1 – Outcome 2.1. Refers to the remarks of Pisut Koomsap (AIT) of splitting its content between the Outcomes 2.1 (curriculum) and 2.2 (syllabuses)
5	10/02/2020	CUT / Tomasz Nitkiewicz	Fifth version – draft version of WP2 Task 2.1 – Outcome 2.1 - updated with workload for course 6,12 and 14 and accepted by WP2 and T.2.1 teams
6	02/03/2020	CUT / Tomasz Nitkiewicz	Sixth version - draft version of WP2 Task 2.1 – Outcome 2.1 - updated after first revision of QCMB remarks
7	04/03/2020	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Final version (before finishing pilot testing) accepted by QCMB with some editorial corrections
8	04/05/2020	CUT / Tomasz Nitkiewicz AIT / Pisut Koomsap	Final version (before finishing pilot testing) accepted by PEC

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1 Executive Summary

The following document presents the key outcome, Master studies in Industrial Engineering curriculum, of the project titled "Curriculum Development of Master's Degree Program in Industrial Engineering for Thailand Sustainable Smart Industry – MSIE4.0" that has been funded with support from the European Commission with CBHE framework of ERASMUS+ program. The outcome is based on cooperation between 6 Thai and 3 EU universities that after identifying the gap between the currently running programs and the needs of industry and students have prepared modernized studying program. The curriculum adopts the logic of backward course design concept, develops its own logic on introducing student oriented learning and active learning principles and covers Industry 4.0 technologies, management and design approaches.

The curriculum is defined with 12 Program Learning Outcomes and 16 courses. The studying program accounts for 2 + 2 semesters (studying and working on thesis). Studying program includes three core courses, related to Industrial Engineering, one obligatory course, covering transversal skills, and 12 electives. The integral part of the curriculum is the set of 16 course syllabuses that are presented in Outcome 2.2.

2 Introduction

The key activities within MSIE4.0 Project is to develop master of science curriculum in the field of industrial engineering that would be supportive for sustainable and smart industry in Thailand. Curriculum is a set of program learning outcomes, list of courses and the structure and schedule of providing them for students in order to achieve the desired outcome: graduates that would be ready to work in Industry 4.0 and contribute to its sustainability. Outcome 2.1 is prepared with the engagement of all the Partners of MSIE4.0 consortium.

Outcome 2.1 is the Curriculum that should meet the abovementioned criteria. It is important to notice that it is based on gap analysis and its reporting, especially in outcomes 1.6-1.7 (MSIE4.0, 2019a, 2019b). Moreover, curriculum is a set of courses that are clearly defined and described in syllabuses, Outcome 2.2 of the Project, and should be considered as an introductory part of the curriculum. The building blocks of the curriculum development are:

- program learning outcomes (PLOs), list of courses, matrix of PLOs and courses relationship and structure of the curriculum – Outcome 2.1 – and
- course objectives and course learning outcomes (CLOs), teaching and learning methods with the assessment approach and evaluation schemes, courses content and description of modules, references and learning resources, time distribution and study load, prerequisites – Outcome 2.2

Since there is intended gap between the two blocks, the sequence of developing them is as follows:

1. developing MSIE 4.0 program by defining PLOs, courses and its relationship to the PLOs (first version of Outcome 2.1)
2. developing course syllabuses by course teams (first version of Outcome 2.2)
3. review of the course documentation by experts – non-members of course teams (official version of Outcome 2.2)
4. review of MSIE 4.0 program (official version of Outcome 2.1)
5. pilot testing of selected courses by partner universities
6. second review of the course syllabuses (final official version of Outcome 2.2)
7. final review of MSIE 4.0 program (final official version of Outcome 2.1)

This version of the MSIE 4.0 program and Outcome 2.1 is official version as indicated in point 4. According to the evaluation criteria of the Outcome 2.1, as defined by QCMB, its content, namely PLOs, should be also

consulted with internal and external stakeholders. The consultation process is complex issue and is spread out in time with the activities as presented in Table 1.

Table 1. Activities during the process of consulting MSIE4.0 curriculum and its PLOs with internal and external stakeholders

Date and place of the activity	Name of the activity	Type of stakeholders	Description
June 6th 2020 Industrial & Technology Park, Częstochowa, PL	Breakfast with Entrepreneurs	External: entrepreneurs, academics, public officers	Brief presentation of MSIE4.0 curriculum and PLOs for open consultation
June 2019 Faculty of Management CUT, Częstochowa, PL	Meeting of Faculty of Management CUT Business Council	External: entrepreneurs, public officers	Consultation of MSIE4.0 curriculum and PLOs with CUT Business Council – the document was accepted
September 23rd 2019 Faculty of Management CUT, Częstochowa, PL	Meeting of Faculty of Management CUT Council	Internal: academics, students	Consultation of MSIE4.0 curriculum and PLOs with Faculty of Management CUT Council – the document was accepted
November 2019 – January 2020 All partner Universities	Reviewing of course syllabuses	Internal: academics	Reviewing of all course syllabuses including its reference to the PLOs and curriculum workload structure – some changes were proposed but not referring to MSIE4.0 curriculum structure and PLOs
February 20th 2020 Faculty of Management CUT, Częstochowa, PL	Meeting of Faculty of Management CUT Business Council	External: entrepreneurs, public officers	Consultation of revised MSIE4.0 curriculum and PLOs with CUT Business Council – the program was accepted
June 2019-May 2020 All partner Universities	Pilot testing of selected courses	Internal: academics, students	Consultation of syllabuses of selected courses including its reference to the PLOs and curriculum workload structure – ongoing process

Since the consultation process would be finalized only after finishing task 2.3 and 2.4 related to pilot testing of selected courses, its results would be fully included in final official version of Outcome 2.1. This circumstances causes also that one of the elements, which is required by evaluation criteria for Outcome 2.1,

namely matrix of classes with a positive recommendation of internal and external stakeholders would be added to the final official version of the document.

The structure of Outcome 2.1 includes executive summary, introduction, its reference to WP1. Gap analysis and its recommendations, and logic of curriculum development and its content.

3 Recommendations for specifications from WP1 – Gap Analysis

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. "Personalizing Your Learning Experience to Support Sustainable Smart Industry" is the summary from the Outcome 1.6. MSIE 4.0 curriculum focuses 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.

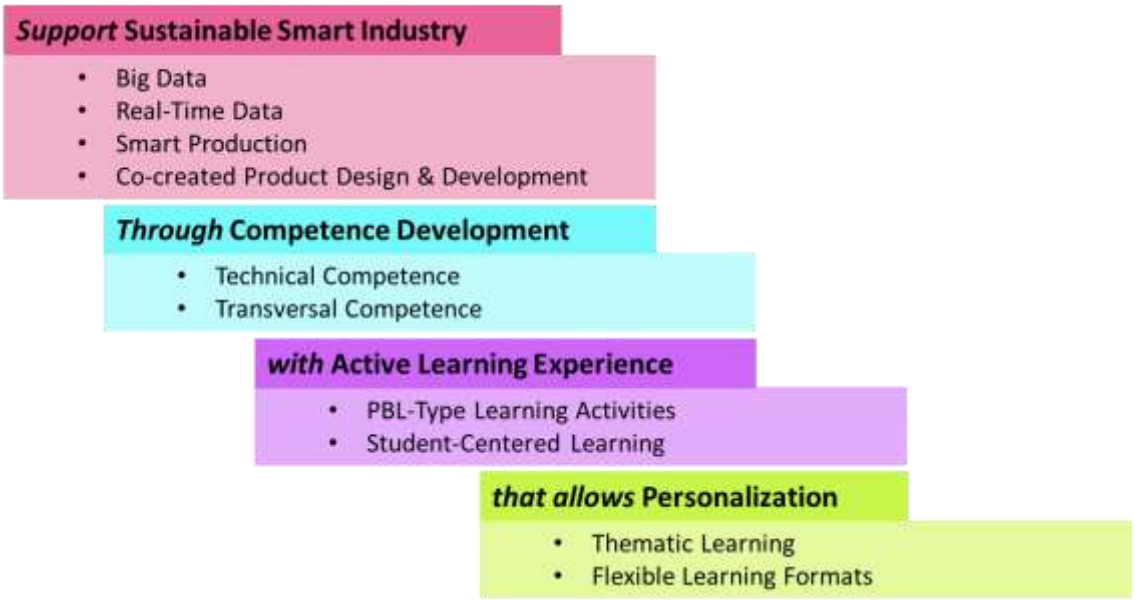

Figure 1. Summary of recommendations for MSIE4.0 curriculum (MSIE4.0, 2019a)

4 Logic of curriculum development of as a process

Basic assumption of MSIE 4.0 curriculum are defined by three different approaches to engineering education development: Bloom's taxonomy, Kolb's model and LOVE model (Figure 2). The approach is based on backward course design concept.

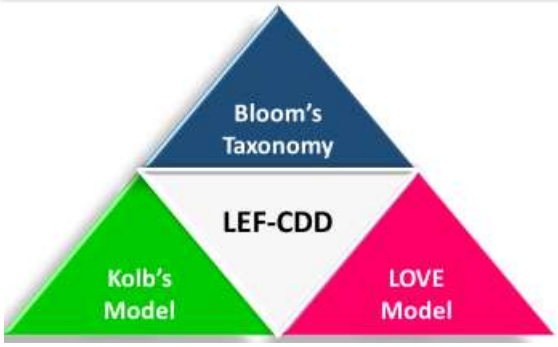

Figure 2. Logic of MSIE4.0 curriculum development (MSIE4.0, 2019a)

The sequence of MSIE4.0 curriculum development should result from the defined and adopted logic. Therefore, the WP1 recommendations and pre-defined objectives of the curriculum are contributing to defining general outline of curriculum as well as its content, approaches, industrial scopes and teaching methods. The recommendations and objectives are used to defined program learning outcomes (PLOs) at the first place, as an attempt to define the desired shape of future graduate of MSIE 4.0 program. As the next step, the set of courses is defined that could fully match the PLOs. Defining the course names and its objectives sets up the ground for defining course specific learning outcomes (CLOs) that could contribute to the achieving PLOs on program level and at the same time could provide appropriate skill set and competences of students. Finally, CLOs are transferred for content that could contribute to the desired outcomes. The complexity of content development, including actual topics of course work, but also its reference to the assessment methods proposed, teaching and learning methods and approaches and possible division within the course on independent module, gives a perfect range for using Bloom's taxonomy, Kolb's and LOVE model for approaching this task.

4.1 Program Learning Outcomes

The set of PLOs was set during multiple sessions, both real and online, with participation of representatives of all Partners of the Project. The primal set of PLOs was defined in a brain storming process with no criticism and objections at first. The session was made during the Consortium meeting in Chiang Mai University in January 2019. The scoping and narrowing has led to the second stage of PLOs defining. The primal set was reviewed and different PLOs were joined together, made more general or more specific as opposite. The second stage has brought 12 PLOs that are further proceeded. At this stage the consortium has agreed on including the objective of graduates autonomy and responsibility as a separate PLO. This is done to meet EQF recommendations but in a way that is more suitable for Thai practices in PLOs defining. The second stage was mainly done through the online meetings and reviewing of written set by all the members. Final stage of the process was the correction and adjustment of PLOs, especially concerning its syntax and relevance to Industry 4.0 specificity. The final stage was also made through online meetings and was finalized by official online meeting of WP2 team and acceptance of PLOs.

According to their results, upon the graduation from MSIE 4.0 program, graduates should be able to:

PLO1. apply knowledge and methods from the advanced science of industrial engineering to design, model and manage Industry 4.0 related complex industrial systems
PLO2. implement smart production and co-created product design & development concepts
PLO3. utilize big data and real time data analytics for supporting smart production, product design & development and advanced manufacturing process
PLO4. exploit online connectivity for strengthening business capability
PLO5. improve sustainability by applying IE related knowledge and competences
PLO6. conduct research in the field of IE
PLO7. manage Industry 4.0 related projects
PLO8. manage Smart Production Systems and Supply Chains

PLO9. lead, manage, work and communicate effectively in interdisciplinary, intercultural and distributed teams
PLO10. perform with high degree of autonomy and responsibility
PLO11. demonstrate continuous self-development by effectively improving competences for professional career
PLO12. demonstrate entrepreneurial attitude towards Industry 4.0 related businesses and its problems

4.2 List of courses

The process of defining courses has started with the draft list of PLOs and the challenge for Consortium members on achieving them with industrial engineering courses. It was done during the meeting in CMU. The draft list of courses has been the outcome of brain storming session of all Consortium members available on the meeting. The list of courses has gone through similar process as the list of PLOs. From the wide draft version of the list, the Consortium members has come to the short list of the courses with scoping, joining and re-orienting the courses submitted at the beginning. The process has started with general assembly and was continued by online WP2 meetings throughout the following months. Finally, the list of 16 courses was defined. The list of courses is presented in Table 2.

The courses are divided into three categories: core courses, compulsory courses and electable courses. The categories of **core and compulsory courses** are similar in a sense that courses are obligatory but different with regard to the reference to industrial engineering field of knowledge. **Core courses** belong to industrial engineering, especially when considered from the point of view of production engineering and management, and are focused on bringing out key technical competences that are required from Industry 4.0 perspective. **Compulsory course** has a horizontal character and refers to the WP1 findings and industry specific needs and is focused on transversal competences. All the remaining courses are **electives** and, while selected by students, form personalized studying program.

The decision over compulsory and core courses were taken in a participatory way by all the partners involved in WP2. The selection was based on WP1 findings and recommendations, industrial engineering specificity and arguments of Partner Universities during the decision process.

Table 2. List of MSIE 4.0 courses

No.	Course name	Course status
1	Enterprise Management in Digital Economy	elective
2	Project Management for Industry 4.0	elective
3	Smart Operations Management	core
4	Quality Management for Extended Enterprise	elective
5	Sustainable Supply Chain Management	elective
6	Digital Factory	core
7	Advanced Optimization: Techniques and Industrial Applications	elective
8	Intelligent Decision Support Systems	elective
9	Applied Data Analytics	core
10	Cyber-Physical Industrial Systems	elective
11	Collaborative Manufacturing Systems	elective
12	Additive Manufacturing for Industry 4.0	elective
13	Innovative Product Design and Development	elective
14	Human-Centric Design for Operator 4.0	elective
15	Customer Experience-Driven Design	elective
16	Communications and People Skills Development for Engineering Leaders	compulsory

In order to maintain the possibility to keep the personalized studying experience for the students most of the program is based on the electable courses. Additionally, a modularity is introduced in order to give an

opportunity for other than students stakeholders to participate in particular educational processes. The general idea of the modularity is based on dividing courses into 3 major categories: **Management, Design and Technology** oriented courses and developing courses with modular structure. It affects the content and hourly schedule of all the courses in a way that each course include a few modules that could be served together as a complex course but also separately as a single experience. The intention of the Consortium and specifically, Course teams, is to develop attractive and comprehensive studying modules that form unique studying experience for interested stakeholders. The University offer would include, besides full MSIE4.0 curriculum, also several studying modules as a stand-alone competence based courses.

4.3 Course teams

After completing the list of courses the course teams have been established. In general, the accession to the course team was open for all the partner Universities and its staff but some specific rules have been defined:

- one person can lead only one course,
- one Thai University should lead at least one course while one EU University should lead at least two,
- Thai Universities should participate in at least four course teams while EU in at least five.

Also some recommendations for the course teams development has been formulated by WP2 team. The most important was that each course team should be compose of at least two members and should have at least one member from Thai and one from EU. WP2 management teams motivated course teams to have regular meetings while progressing the course development. AIT has proposed using its online platform to organize course teams meetings. The process of establishing teams needed some time and was several times a subject of WP2 team meetings. Some final corrections were discussed and introduced during the meeting on CUT in June 2019.

4.4 Relationship between the courses and PLOs

The relationship between the PLOs and courses is assessed by the consortium member and is summarized in Figure 3. Coverage of PLOs by coursesThe relationship was assessed primarily by course teams with nine grades QFD originating scale. Additionally, all Universities as Consortium members could add its evaluation of PLO – course relationship. The results are average evaluations of the relationship.

		COURSES IN MSIE4.0																
	PROGRAM LEARNING OUTCOMES	Enterprise Management in Digital Economy	Project Management for Industry 4.0	Smart Operations Management	Quality Management for Extended Enterprise	Sustainable Supply Chain Management	Digital Factory	Advanced Optimization: Techniques and Industrial Applications	Intelligent Decision Support Systems	Applied Data Analytics	Cyber-Physical Industrial Systems	Collaborative Manufacturing Systems	Additive Manufacturing for Industry 4.0	Innovative Product Design and Development	Human-Centric Design for Operator 4.0	Customer Experience-Driven Design	Communications and People Skills Development for Engineering Leaders	Av.
	Upon the graduation from MSIE 4.0 program, graduates should be able to	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	coverage
PLO1	apply knowledge and methods from the advanced science of industrial engineering to design, model and manage Industry 4.0 related complex industrial systems	0,92	0,67	0,83	0,83	0,83	1,00	1,00	0,83	0,50	1,00	1,00	1,00	0,83	1,00	1,00	0,14	**0,84**
PLO2	implement smart production and co-created product design & development concepts	0,53	0,28	0,36	0,42	0,17	0,67	0,11	0,50	0,25	1,00	1,00	1,00	1,00	1,00	1,00	0,17	**0,59**
PLO3	utilize big data and real time data analytics for supporting smart production, product design & development and advanced manufacturing process	0,42	0,36	0,33	0,83	0,83	0,25	0,25	0,83	0,83	0,75	0,50	0,33	0,58	0,11	0,19	0,14	**0,47**
PLO4	exploit online connectivity for strengthening business capability	0,28	0,42	0,11	0,83	0,50	0,50	0,03	0,08	0,11	0,75	0,42	0,08	0,33	0,03	0,08	0,17	**0,30**
PLO5	improve sustainability by applying IE related knowledge and competences	0,33	0,44	0,28	0,25	0,36	0,11	0,42	0,11	0,42	0,75	0,42	0,42	1,00	0,36	0,44	0,17	**0,39**
PLO6	conduct research in the field of IE	0,36	0,53	0,75	0,33	0,78	0,33	1,00	0,50	0,83	0,33	0,50	0,75	1,00	0,78	0,53	0,03	**0,58**
PLO7	manage Industry 4.0 related projects	1,00	1,00	0,36	0,83	0,36	1,00	0,33	0,33	0,83	0,28	0,36	0,33	0,92	0,28	1,00	0,17	**0,59**
PLO8	manage Smart Production Systems and Supply Chains	1,00	0,42	0,78	0,33	1,00	0,83	0,28	0,42	0,50	0,50	1,00	0,28	0,58	0,11	0,08	0,08	**0,51**
PLO9	lead, manage, work and communicate effectively in interdisciplinary, intercultural and distributed teams	0,50	0,28	0,25	0,11	0,83	0,25	0,03	0,08	0,08	0,25	0,08	0,11	0,53	0,08	0,61	1,00	**0,32**
PLO10	perform with high degree of autonomy and responsibility	0,11	0,33	0,08	0,08	0,28	0,33	0,11	0,11	0,08	0,28	0,08	0,11	0,28	0,08	0,17	0,53	**0,19**
PLO11	demonstrate continuous self-development by effectively improving competences for professional career	0,14	0,53	0,08	0,08	0,17	0,36	0,08	0,25	0,11	0,25	0,25	0,28	0,53	0,17	0,67	1,00	**0,31**
PLO12	demonstrate entrepreneurial attitude towards Industry 4.0 related businesses and its problems	0,83	0,28	0,33	0,11	0,42	1,00	0,08	0,08	0,25	0,25	0,08	0,08	1,00	0,03	1,00	0,33	**0,39**

Figure 3. Coverage of PLOs by courses

4.5 Structure of the curriculum

The general assumptions for the structure of curriculum are based on joining Thai and EU approaches and practices. The number of courses is determined by regulatory framework and practices in Partner Universities. Since, the existing differences cannot be undone by the contribution of Partners only, the flexible approach is used. Thai Partner Universities have 4 or 5 courses foreseen for one semester while EU Partners 6. Each semester would include 1 or 2 obligatory courses and remaining part of electable courses. Last two semesters are dedicated to development of master theses.

Table 3. General structure of MSIE 4.0 curriculum

	THAILAND	EU Partners
1st SEMESTER	3/4 + 1 COURSES	5 + 1 COURSES
2nd SEMESTER	3/4 COURSES	6 COURSES
3rd SEMESTER	MASTER THESIS	MASTER THESIS
4th SEMESTER	MASTER THESIS	MASTER THESIS*

* Number of semester in EU countries depends on organization of 1st level studies and national and university practices. Therefore, 4th is not necessary if the 1st level studies cover 3,5 year studying period.

The structure of the curriculum is presented on the example of its possible implementation by AIT, Project leader (Table 4) and CUT (Table 5). The difference is related to the credit systems and number of courses per semester. In Thailand the courses are typically with much more workload than courses in EU countries. Therefore, proportionally, courses in Thailand are prescribed with higher number of credits. As opposite, in EU countries the number of courses is higher with relatively lower number of credits per each course.

Table 4. Example of general structure of MSIE 4.0 curriculum - AIT

Academic Program: **Industrial and Manufacturing Engineering**	
Area of Specialization: **Industrial Engineering to Support Sustainable Smart Industry**	
Number of Required Course:	**3+1**
Total Number of Required Course Credit	**9+3**
Number of Elective Course	**12**
Minimum Credit Requirement	**49**
Minimum Credit Requirement for Coursework	**27**
Minimum Credit Requirement for Thesis	**22**
Additional Requirements:	**IE Colloquium and Student Conference**

Table 5. Example of general structure of MSIE 4.0 curriculum - CUT

Academic Program: **Quality and Production Engineering**	
Area of Specialization: **Industrial Engineering to Support Sustainable Smart Industry**	
Number of Required Course per semester:	**5+1 [6]**
Total Number of Required Course Credit per semester	**24 + 6 [30]**

Number of Elective Courses	**12**
Minimum Credit Requirement	**90**
Minimum Credit Requirement for Coursework	**60**
Minimum Credit Requirement for Thesis	**30**
Additional Requirements:	**IE Colloquium and Student Conference**

Since the practices of organizing curriculum are different for Thai Partners some primary requirements have been relaxed. In MSIE 4.0 curriculum 3 courses are named core courses and are obligatory for students. For specific and justified cases, Thai University could have 2 core courses that would be core and obligatory. Recommendation from WP2 team is to select *Applied Data Analytics* and *Digital Factory* as core courses in such case.

Additionally, the order of the course offering is not fixed and can be vary according to the implementation of each Partner. In order to achieve that, it is important that the 16 courses included in the curriculum should not have prerequisites related to other courses included in the curriculum.

4.6 Possibilities of calculating credits to ECTS

Since the credit systems are different in Thailand and in EU the integrating approach has been developed. In the first step, courses and its work-load structure were adjusted to the Thai specific practices with the assumption of keeping the same credit limits for every course (see Table 7). Secondly, the structure and total amount of work-load has been recalculated to fit ECTS requirements. Some general assumptions are made in order to fit European Credit Transfer System requirements as follows:

1. 1 ECTS = 25 h of workload including contact and non-contact hours
2. non-contact hours include: self-studying, group learning and project development
3. contact hours include L-W-L hours (accounted for) + exams and individual consultations (not accounted for in the Table 6)
4. there should be at least 120 ECTS for whole 4 semester program and eventually 90 ECTS for 3 semester program[1]
5. there should be 30 ECTS per semester

Since ECTS are calculated on the number of contact and non-contact hours it is important to keep the balance between contact and non-contact hours within each course and MSIE4.0 program as a whole. This would be regarded as a recommendation for the curriculum and course development within the workload structure.

Table 6. Possible variants of 3 Thai credit course with regard to contact hours work-load structure

work-load structure - contact hours within the course Lecture – workshop - lab (number of hours per week)	Total number of contact hours	Recommendations for total amount of non-contact hours	Number of ECTS for course	Total amount of hours
(3-0-0)	45	75-105	5-6	125-150
(2-2-0)	60	90-140	6-8	150-200
(1-4-0)	75	100-125	7-8	175-200

[1] Since BSc studies could take 3-4 years, MSc program could be also limited to 1,5 year / 3 semesters

(2-0-3)	75	100-125	7-8	175-200
(1-2-3)	90	110-160	8-10	200-250
(1-0-6)	105	120-145	9-10	225-250
(0-6-0)	90	110-160	8-10	200-250
(0-4-3)	105	120-145	9-10	225-250
(0-2-6)	120	80-130	8-10	200-250
(0-0-9)	135	90-120	9-10	225-250

The calculation of ECTS is made on the basis of total sum of contact and non-contact hours with the assumption presented in point 1 above that 1 ECTS is roughly 25 hours of workload. The approach to recognize credits differently for different types workload hours (Lectures, Workshops or Laboratories) causes the difficulty in transferring them to ECTS. Therefore, the recommendation for course workload breakdown is to avoid defining courses with relatively low (i.e. 3 hours) and relatively high (8-9) number of contact hours.

4.7 Structure of workload

The number of hours and structure of learning activities are presented in Table 7. Lecture, workshop and Lab are contact hours within the course, while Project and Self-study are non-contact hours.

Table 7. Types of teaching approaches and structure of workload in MSIE4.0 courses

No.	Course name	Lecture	Workshop	Lab	Project	Self-study
1	Enterprise Management in Digital Economy	15	60		30	30
2	Project Management for Industry 4.0	30	30		30	15
3	Smart Operations Management	30	30		30	30
4	Quality Management for Extended Enterprise	30	30		30	30
5	Sustainable Supply Chain Management	15	60		15	45
6	Digital Factory	30		45	30	30
7	Advanced Optimization: Techniques and Industrial Applications	45			15	30
8	Intelligent Decision Support Systems	15	60		15	60
9	Applied Data Analytics	30	30		40	45
10	Cyber-Physical Industrial Systems	30		45	30	30
11	Collaborative Manufacturing Systems	30	30		30	15
12	Additive Manufacturing for Industry 4.0	15	30	45	30	40
13	Innovative Product Design and Development	15	60		30	30
14	Human-Centric Design for Operator 4.0	15	60		30	30
15	Customer Experience-Driven Design	30		45		60
16	Communications and People Skills Development for Engineering Leaders	15	60			45

Upon finishing MSIE4.0 studies graduate should be equipped in both technical and transversal competences and ready to face Industry 4.0 challenges from the perspective of technology, management or relationships. The experience coming from MSIE4.0 studies would be personalized and based on active learning approach and should result in providing flexible and open set of skills that could be immediately used and developed. Through the learning processes, graduates would be prepared for using sustainable and smart approach while facing real-life problems. The approach used to solve the problems would be also affected by the active

learning principle that would be used upon the studies and would support self-development and self-evaluation of graduates.

5 References

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