WP 1 - Gap Analysis

Outcome 1.6 - Competitive factors for the curriculum

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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 this report. The process of finding the referred competitive factors was based on Blue ocean strategy, applied in several brainstorming cycles with the project partners. After identifying the competitive factors for curricula for Master's Degree in Industrial Engineering to support sustainable smart industry, a new set of brainstorming cycles was conducted to apply the Eliminated (E), Reduce (R), Raise (R) and Create (C) – ERRC grid, to obtain a value curve representing the competitive strategy for the MSIE4.0 program. 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.

2 Introduction

Different sets of competitive factors may influence the way the curriculum may be attractive and effective for creating highly capacitated Industrial Engineering professionals. Thus, this report has the objective to show the results of a demand for the competitive factors for the MSIE4.0 program.

2.1 Competitive factors

A competitive factor is a factor valuable to customers and for that reason, considered as key to the success of a product or service. In general, such a characteristic that will be important for the success of the product or service could include the price, quality, employee competences, ease of use, lead times and quick response, among others (Lau, 2002). Publications about competitive factors on educational systems refer market profile/ brand identity, organizational expertise/ core competences, innovation, and service quality (de Silva & Chitraranjan, 2018; Mazzarol & Norman Soutar, 1999).

For an understanding of the curriculum it is essential to recognise 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).

These challenging times of the fourth industrial revolution, of rapid and profound changes of technologies and systems, will have a profound impact and yet to be understood in its fullness, in society, in the economy, in business, and in individuals. In order for a curriculum to be able to cope with this rapidness of change, it should be characterized by flexibility in the process of delivery and in the process of serving the students.

2.2 Blue ocean strategy for identifying competitive factors

Blue ocean strategy, introduced by (Chan Kim & Mauborgne, 2005), was applied for identifying the competitive factors. Blue ocean strategy focuses on value innovation by the simultaneous pursuit of increasing of benefits for customers and decreasing costs for a company to open up a new market space, and create new demand. As a result, competitors become irrelevant, and a win-win situation is created.

A tool used for building a compelling blue ocean strategy is a strategy canvas illustrating information in a graphic form (Figure 1). Appeared on the canvas are factors industry currently competes on and will invest in (the horizontal axis), the offering level that customers receive from each factor (vertical axis), the value curve(s) of current competitive offering(s) on the market, and the value curve of a new offering resulted from the assessment of the current factors and the introduction of new factors.

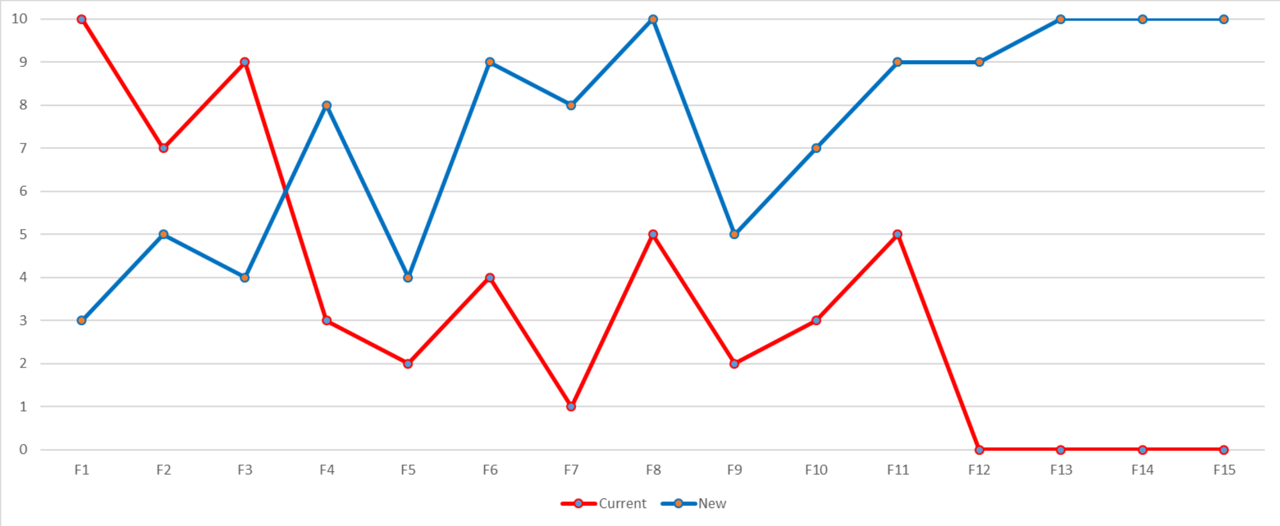


Figure 1. Illustration of a Blue-Red ocean strategy canvas

From the competitive assessment, each individual current factors are either eliminated, reduced or raised, and new factors are introduced to strengthen the new offering. Eliminated (E) and reduced (R) factors lower the costs down while raised (R) and created (C) factors increase the benefits, which may be referred by the ERRC factors.

All good strategies have focus. When looking at their value curves, it is clear what they offer. All strategies are also unique and diverge from their competitors. They always stand out. Last but not least, all good strategies have clear compelling taglines. The conclusion drawn from the value curve of the new offering will give a strategic direction for execution of the new offering.

3 Competitive Factors for MSIE 4.0

This section presents factors MSIE curricula compete on to support sustainable smart industry and a proposed strategy for MSIE 4.0.

3.1 Implementation of blue ocean strategy for identifying MSIE 4.0 competitiveness

Blue ocean strategy was applied in this curriculum development in four steps:

1. Identify competitive factors.
2. Assessing current competitive offering(s) on the market.
3. Creating a new offering.
4. Reflect and consolidate the results and process.

A working group of project experts, simultaneously aware of the use of the blue ocean strategy and deeply involved in the analysis of WP1 data, initiated the process of implementation of the blue ocean strategy. A couple of brainstorming sessions were conducted to identify factors MSIE curricula may compete on to support sustainable smart industry. According to the results from the previous tasks on reviews of curricula and teaching and learning tools, and on surveys on the needs of industry and students, an initial list of fifteen factors was generated covering five categories: pedagogy, competence, industry needs to attain Industry 4.0, team's insight and teaching and learning methods. A one to ten weight scale was used for assessing the offering levels for all factors, and the descriptions for the scale were also determined for all factors. The working group performed an initial assessment to obtain the value curve for the current offering and proposed the value curve for a new offering (MSIE 4.0). The obtained initial strategy canvas was used as a starting point for a larger group discussion. The members were asked to assess the factors and both value curves, and make recommendations. A few brainstorming sessions were conducted to go through the recommendations.

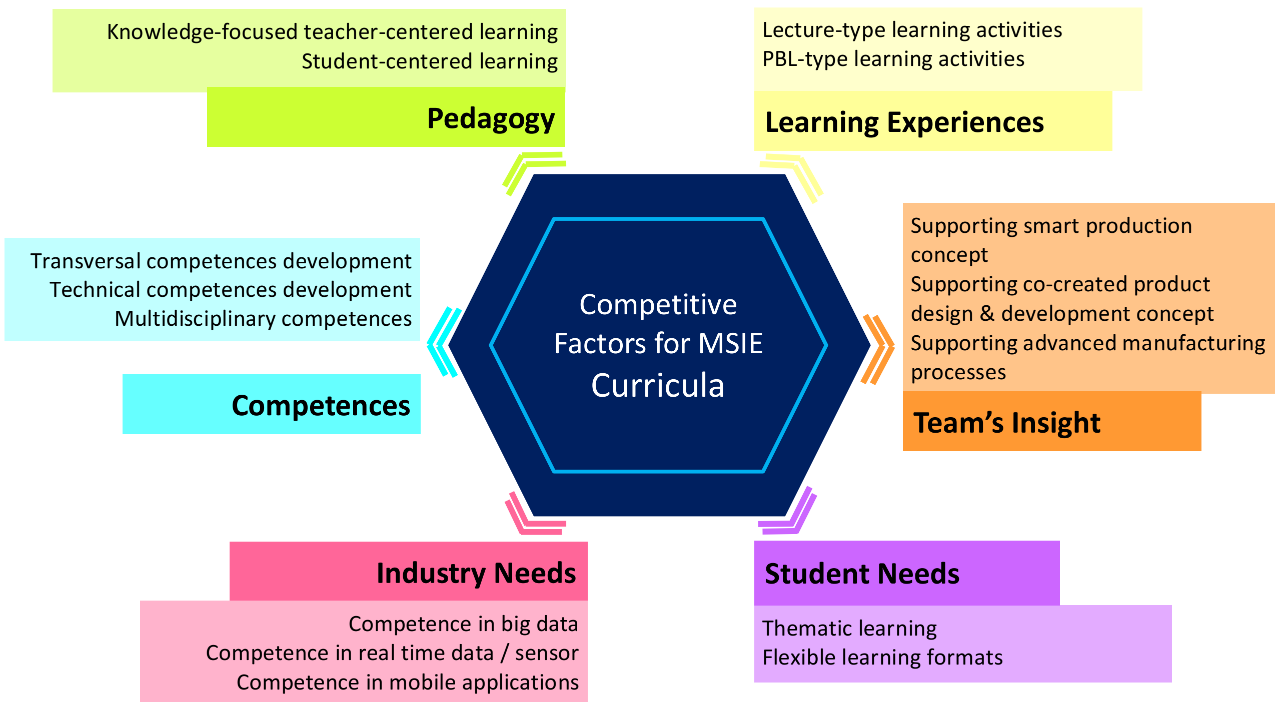


Figure 2. The identified competitive factors for MSIE curricula to support sustainable smart industry

3.2 Identified competitive factors for MSIE Curricula to support sustainable smart industry

This section summarizes the factors that were identified as providing a competitive advantage to the MSIE curricula to support sustainable smart industry. After rounds of discussion, a few factors were removed, the remaining factors were polished, and new factors were introduced. The total number of factors remains fifteen, covering six categories which are pedagogy, competence, industry needs to attain Industry 4.0, student needs, team's insight and learning experiences as illustrated in Figure 2. In the remaining of this section, the dimensions and factors will be described, so as the rationale sustaining the choices made by the team.

An Industrial Engineer needs to mobilise knowledge, skills, attitudes and ethical behaviours in a professional practice environment. The mobilisation of these resources makes the pieces of evidence of the Engineer's competences (Le Boterf, 1997; Perrenoud, 2004; Zarifian, 2001). The fact is that the professional practice competences' needs are rapidly changing. Yet the way the education system try to change in order to meet these needs as often a time lag of years (WEF, 2016a). Thus, the development of a curriculum that will contribute for the development of the needed competences, and with the flexible structures to cope with a fast changing demand, will be a competitive curriculum.

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. Besides the technical competences regarding the role of Industrial Engineering in Industry 4.0, which were identified in this project, it was also possible to identify a need to develop transversal competences. This need was a strong emphasis on the results of the surveyed industries and also of the surveyed students, which makes **transversal competences** to be one of the competitive factors for MSIE4.0. The results of the questionnaires gave a slightly higher relative importance to the following ones: Adaptability and ability to change, Teamwork and Communication skills.

Moreover, the importance of transversal competences for the jobs of the future has been reinforced by several studies (Gray, 2016; Soffel, 2016; WEF, 2015, 2016b). A recent study from the World Economic Forum listed the following transversal competences:

> *"Proficiency in new technologies is only one part of the 2022 skills equation, however, as 'human' skills such as creativity, originality and initiative, critical thinking, persuasion and negotiation will likewise retain or increase their value, as will attention to detail, resilience, flexibility and complex problem-solving. Emotional intelligence, leadership and social influence as well as service orientation also see an outsized increase in demand relative to their current prominence." (WEF, 2018, p. ix)*

Technical competences are mainly related to concepts, knowledge, methods, and technology of specific areas of knowledge and professional activity. In the case of this project, these should be related to industry 4.0 and the results for the research developed with industries and students. Thus, it should be related to the main domains of application, the main technologies and the team's insight into their cross relation.

The four main domains of the applications of Industry 4.0 that were considered in the research for the analysis of industry needs include the following: (1) Smart Products - Co-created Design, (2) Smart Factory - Intelligent Manufacturing System, (3) Smart Operations - Real Time Controlling, Adjusting and Monitoring Process and (4) Data Driven Services - Integrated Business and Operational Data Management. The task for MSc level education in IE is to develop competences that would enable the graduates to support industry-driven exploration and development within these domains in order to gain competitive advantage. It seems that the four domains cover wide and diversified areas of competences and, therefore, the research was focused on their assessment and narrowing them to the group of most significant and needed ones.

These domains should be considered from the point of view of supporting technologies and areas of applications. The main application areas that should be supported by MSc in IE curricula were an outcome of several iterations with the project's team. These applications 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 applications in the most efficient manner, according to industry needs analysis, are big data, real time data with sensor and mobile.

According to the results of industry needs analysis and its crosscheck with expert assessment the **support for advanced manufacturing process** has already significant coverage in current curricula and should be updated to current Industry 4.0 needs and enhanced. This could be achieved through a focus on system IT solutions, cross-departmental and external information sharing facilities, development of autonomous production processes and self-guiding workpieces and digitization level of equipment and value chains. The use of mobile devices, sensors and big data seem to be must have issues in order to give a proper momentum to the development of this domain. The requirements towards IE graduates would potentially become more multidisciplinary and holistic from the perspective of manufacturing processes and value chains.

The big gap and higher expert expectations are related to the **support of smart production concept**. The content and competences enhancing performance within this domain should be built upon digital modelling and automatization of data flow within the manufacturing processes and within the external relationship with different stakeholders. Certainly, support should also cover computer-aided systems, in a sense of integrated solutions as well as specific systems. The issue that should be also addressed here is related to the hardware and software aspects of both internal and external data flow. It means, again, high competences in real time data handling, sensors and big data use.

Another competitive factor of the curriculum in IE is identified as a **support for co-created product design and development**. This domain of application seemed to be completely absent so far, and therefore, requires attention and new competence build-up model in IE education. The support for co-created product design could be understood as a managerial as well as technical competence. Enabling participation of consumers and business partners in the design and construction stages of the product life cycle is a matter of well-organized decision making process and technical facilities. The orientation within the market and consumer-specific expectations could be also enhanced through equipping products with appropriate add-on functionalities that are based on a remote control, self-reporting, monitoring and two-way communication.

The trinity of Industry 4.0 technologies: big data, real time data with sensor and mobile, should not be regarded only as a tool for supporting application domains but also as a stand-alone set of competences of MSc in IE graduates. Therefore, the competitive factor of an up-to-date curriculum is to incorporate competences into its program and course-specific learning outcomes. It seems that the approach towards these technology-related competences should be comprehensive and interdisciplinary. It should combine software and hardware related competences, knowledge with practical skills, control and steering with designing.

As Figure 3 suggests, the technologies and their use could be evaluated and cross-checked with IE range and scope. Basing on the results of industry survey and opinions of IE educational experts the competences related directly to these technologies and application domains could be narrowed to specific fields. The true competitive curriculum in IE should provide appropriate coverage for these outcomes, most preferably, through complex and problem-based teaching. Additionally, competitiveness would also depend on curriculum conformity level with regional industry specificity. Therefore, some flexibility and purposeful specializations within the curriculum should be provided. Finally, the selection of technology-domain key areas should not limit the actual content and competences provided within IE curriculum. Openness and some type of technological foresight should be also part of developing and updating the curriculum.

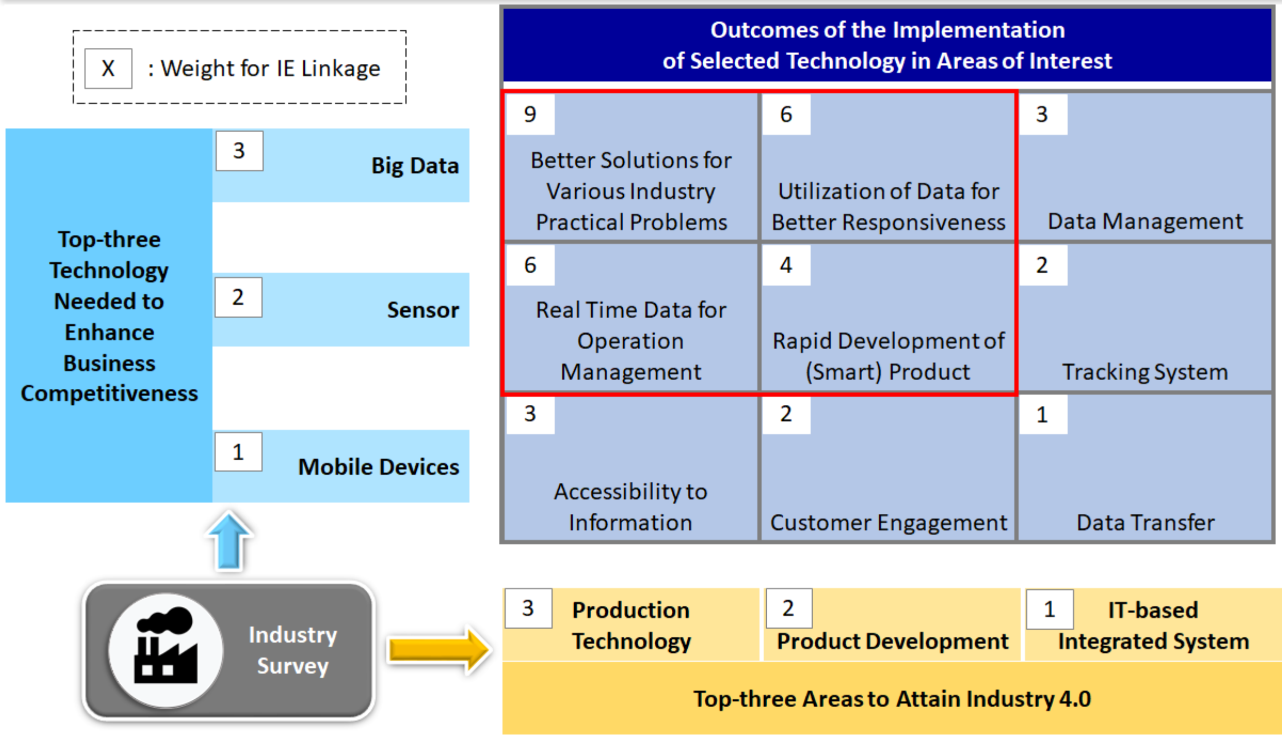


Figure 3. Outcomes of the implementation of key technologies with regard to application domains

The competitive factors of IE master curriculum should be considered also from the perspective that is more general than technologies or its application areas. As the industrial and student surveys indicate strategic approach towards Industry 4.0 adaptation is not developed neither in companies nor within higher education, the adaptation process should be designed and implemented within strategic and complex approach. This is only possible when technological development, human resources and economic and market perspectives are considered simultaneously and are addressed with an integrated strategic approach. Therefore, the curriculum may also consider to provide the opportunity to develop necessary competences for that challenge and preferably to provide them within a whole education process.

As pointed out previously, competences are directly linked with an action, in which a person mobilizes its resources to solve a problem, or to accomplish an objective. Thus, competences need a context for being applied and also for being developed. This means that an experiential education environment will allow the development of competences. This type of environment is the basis for a student-centred learning system, which has been materialized in Engineering Education as Active Learning approaches. In opposition to this type of environment, the majority of teachers all around the world have been implementing Knowledge-focused teacher-centred learning. In this type of system, the teacher acts in great control of the learning process, focusing in transferring knowledge to students, expecting that they will somehow understand the information they are receiving, create meaningful connections with their previous knowledge, reflect on it, and develop the required competences.

Active Learning in Engineering Education refers to a large set of different teaching and learning approaches, which can be more or less student-centred (but always student-centred), as pointed out by Prince (2011), in the Active Learning continuum. At one end of the continuum, there are short active learning class activities, less student-centred and with a higher control from the teacher. In the other end of the continuum, there are approaches relying on the high autonomy of the student, like problem and project-based learning (PBL) approaches. Although the higher number of examples of best practices, in both Thai and European set of programs, are related to project-based learning approaches, in European countries is much more common to develop these approaches dealing with interdisciplinary problems, and/or interacting with industrial partners solving real problems. Thus, it is possible to identify what can be called as an "**Interdisciplinary Industrial PBL**" competitive factor. This factor would bring several potential benefits:

1. Using one of the most comprehensive teaching-learning approaches for the development of competences, which is based on the identification, formulation and solving problems through the development of projects in teams of students.
2. Being able to deal with interdisciplinary problems, which are, by nature, closer to most common problems graduates will have to identify, formulate and solve.
3. Finally, will allow to solve the needs of industries with a flexible and adaptable curricular approach, during operational planning and implementation of curriculum.

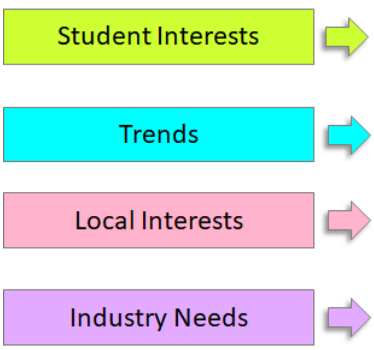
As referred at previous point 2, real problems need, most of the times, to mobilize concepts from different areas of knowledge, interconnecting deep technical competences with transversal competences. This means that interdisciplinary competences may also be considered a competitive factor for a competitive curriculum.

Considering that dealing with different profiles of students could increase the attractiveness and diversity of results a program could obtain, the development of competences aligned with Industry 4.0, could benefit from a flexible set of structural and pedagogical approaches.

Thematic learning is an approach to 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.

Thematic learning requires instructors to sit together at the early stage to identify a common theme which can be varied from batch to batch and to integrate it with a curriculum. Courses are then adjusted accordingly. In each course, topics remain a skeleton, but an instructor will prepare examples and activities to support the theme.

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. Figure 4 illustrates potential sources for theme identification.



Thematic Learning

Course (credit)					
I (3)	Topic 1	Topic 2	Topic 3	…	Topic n
II (3)	Topic 1	Topic 2	Topic 3	…	Topic n
III (3)	Topic 1	Topic 2	Topic 3	…	Topic n
IV (3)	Topic 1	Topic 2	Topic 3	…	Topic n
…	…	…	…	…	…
XV ( )	Topic 1	Topic 2	Topic 3	…	Topic n

Figure 4. Thematic learning

Flexibility in learning is a value creation in supporting equal opportunity of learning that opens up an opportunity for many prospective students who may be at a distance or may not be able to take leave form their job duty, in entering the process without sacrifice of academic quality. Flexibility in learning frees learning process from limitations imposing in the traditional setup. Flexible learning, however, is not limited to distance learning or online learning.

Learning process composes of three key components: functional component (i.e., ideal curriculum, Formal curriculum, course content), structural component (i.e., instructor, students, physical resources) and mechanic/procedural component (i.e., teaching and learning methods, organization of the environment, planning and delivering classes). Flexibility in learning can be seen as the outcomes of the modifications of these components. Modification in a functional component includes a reconfiguration of course offering such as applying modular concept for structuring a course. Modification in structural component includes providing a chance for a student to take a similar course from partner universities. Modification in a mechanic component includes relaxing learning time and place. Figure 5 illustrates an example of modifying functional component for flexibility in learning. When a curriculum equips with both thematic learning and flexibility in learning, learning will never end.

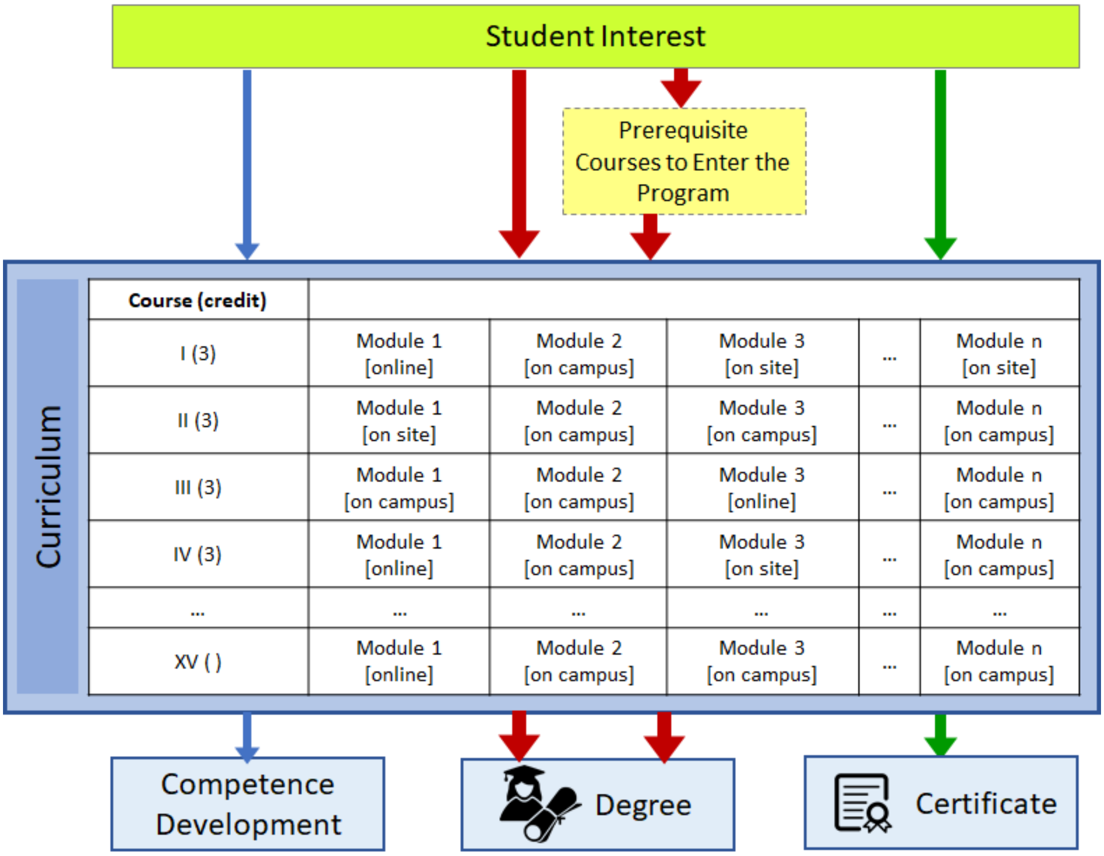


Figure 5. Example of modifying functional component for flexibility in learning

3.3 Strategy canvas of MSIE 4.0

This section presents the creation of MSIE 4.0 strategy. For all competitive factors identified in the previous section, the descriptions were identified at both ends of the scale in order to provide common reference for all members during the assessment. Table 1 presents the description of scale for value offerings.

Table 1. Descriptions of scale for value offerings

Category	Competitive Factors	Scale	
		0	10
Pedagogy	Knowledge-focused teacher-centered learning	Have never been applied	Intensively apply
	Student-centered learning	Have never been applied	Intensively apply
Learning Experiences	Lecture-type learning activities (e.g., lecture, showing VDO materials)	Have never been applied	Apply in all courses
	PBL-type learning activities (e.g., project, industrial practical training)	Have never been applied	Apply in all courses
Competences	Transversal competences development	No training	Embed skill training in all courses
	Technical competences development	No training	Embed skill training in all courses
	Multidisciplinary competences	One disciplinary	Several disciplinary
Industry Needs to Attain Industry 4.0	Competence in big data	Unable to apply big data knowledge in practice	Able to apply big data knowledge effectively in practice
	Competence in real time data / sensor	Unable to apply real time data knowledge in practice	Able to apply real time data knowledge effectively in practice
	Competence in mobile applications	Unable to apply mobile application knowledge in practice	Able to apply mobile application knowledge effectively in practice
Team's insight	Supporting smart production concept	Not support	Fully support
	Supporting co-created product design & development concept	Not support	Fully support
	Supporting advanced manufacturing processes	Not support	Fully support
Student Needs	Thematic learning (batch, region)	Not support	Fully support
	Flexible learning formats	Not support	Fully support

As aforementioned, a few rounds of brainstorming sessions were conducted for creating an MSIE 4.0 value curve. According to the final assessment, nine out of fifteen factors exist in the current curricula. No factor was eliminated. Two factors which are knowledge-based teacher centred-learning and lecture-type learning activities were recommended to be reduced and put more emphasis on active learning. Initially, there was an idea of eliminating knowledge-based teacher centred-learning but some members foresaw the necessity of having it. Other seven current competitive factors were recommended to be raised. Student-centred learning, PBL-type learning activities, competences, as well as supporting smart production and advanced manufacturing processes are in this group. Seven new factors were created. They are mainly from industry needs to attain Industry 4.0, and student needs for learning flexibility. Table 2 presents the summary of eliminate, reduce, raise and create grid for MSIE 4.0 competitive factors.

Table 2. MSIE4.0 ERRC eliminate, reduce, raise and create grid

Eliminate	Raise
-None-	1. Student-centered learning 2. PBL-type learning activities 3. Transversal competence development 4. Technical competence development 5. Multidisciplinary competences 6. Supporting smart production concept 7. Supporting advanced manufacturing processes
Reduce	**Create**
1. Knowledge-based teacher-centred learning 2. Lecture-type learning activities	1. Competence in big data 2. Competence in real time data / sensor 3. Competence in mobile applications 4. Supporting co-created product design & development concept 5. Thematic learning 6. Flexible learning formats

Figure 6 presents the final strategy canvas for MSIE 4.0. The value curve of the MSIE 4.0 curriculum is unique and stands out from the current curricula value curve. As can be seen from the canvas, 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 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. A compelling tagline for MSIE 4.0 curriculum is "Personalizing Your Learning Experience to Support Sustainable Smart Industry".

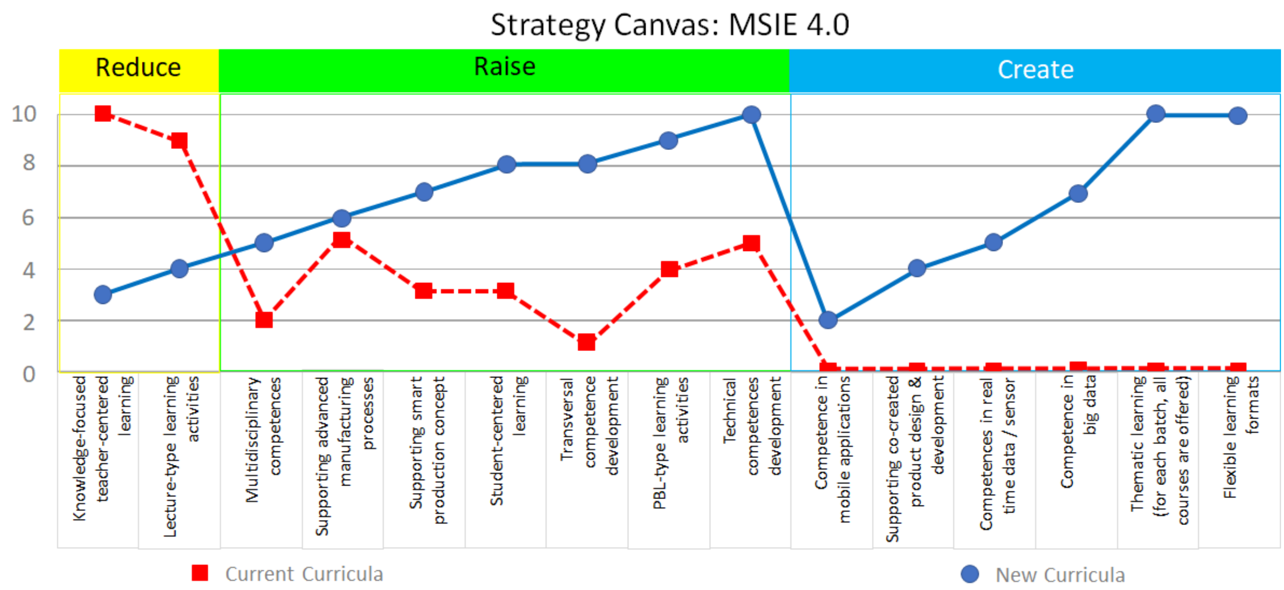


Figure 6. Strategy canvas of MSIE 4.0

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