Module Specification:

M03 Industry 4.0

Within the Erasmus+ KA2 Capacity Building Project (CBHE)

WORK4CE – Cross-domain competences for healthy and safe work in the 21st century

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WORK4CE

1 Summary

The Industry 4.0 module aims at bringing the students the introduction knowledge on the key emerging technologies which are the core of Industry 4.0 in order to have them understand the technological challenges for a digital transformation towards Industry 4.0.
The module starts with an introduction on the history of industrialisation and Industry 4.0, with the differences and enhancements of each of the different industrial revolutions.
After the description of Industry 4.0 and the technologies, the module takes in consideration the consequences of the industry 4.0 revolution (change management) on the organisation of work, of the organisations, of the economic impact and of the technological switch the organisations have to make or will undergo.
Students will choose a set of electives on a more in depth exploration of the key technologies of Industry 4.0.
Finally industry 4.0 case studies are used to give a round-up and example of implementation.

Overall Learning Outcome:

- Students learn the roots of digital transformation towards Industry 4.0 and understand how to overcome the challenges of digital transformation projects.
- Students get knowledge on the key emerging technologies which are at he core of Industry 4.0 in order to have them understand what the technological challenges are for a digital transformation towards Industry 4.0.
- Students learn about the consequences of the process of introduction of Industry 4.0 into an organisation: the change management and effects on project management.
- Students can propose argumented steps to be taken to implement digital transformation (technologies, project management techniques) in an industry 4.0 setting.

Target Group Analysis:

- Master students: see the interrelations between technologies and the connections to existing industrial installations/machines/plants/production processes in order to understand how projects will span and connect a whole range of different applications for digital transformation
- Long life learning student: need an update of knowledge to be able to function in digital transformed organisations
- Academic Staff: need to have in depth knowledge on technologies of the 21st century. Being able to guide the digital transformation towards an interconnected environment.

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2 Introduction to the module

The Industry 4.0 module aims at bringing the students the introduction knowledge on the key emerging technologies which are the core of Industry 4.0 in order to have them understand the technological challenges for a digital transformation towards Industry 4.0.

The module starts with an introduction on the history of industrialisation and Industry 4.0, with the differences and enhancements of each of the different industrial revolutions.

After the description of Industry 4.0 and the technologies, the module takes in consideration the consequences of the industry 4.0 revolution (change management) on the organisation of work, of the organisations, of the economic impact and of the technological switch the organisations have to make or will undergo.

Students will choose a set of electives on a more in depth exploration of the key technologies of Industry 4.0.

Finally industry 4.0 case studies are used to give a round-up and example of implementation.

Industry 4.0 is the term used to described the 4th industrial revolution (fig 1)

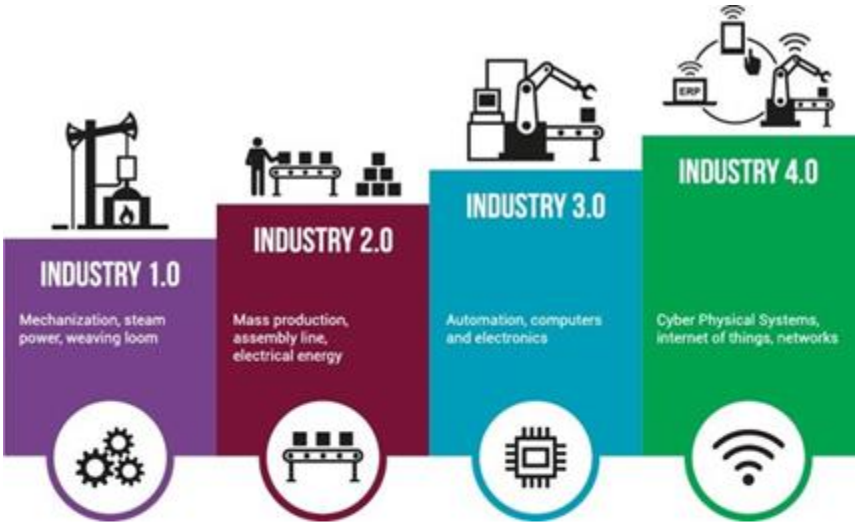

Figure 1: Industrial revolutions overview

The first industrial revolution was the switch from rural employment in agriculture to a mechanisation as power tools (steam engines) became available.
The second industrial revolution was the start of standardization and mass production, which came with the use electric energy as a power resource.
The third industrial revolution was the automation of processes and manufacturing made possible by the invention of electronics and due to increasing computing power. In general Industry 3.0 could be described as automated production.

Industry 4.0 is the fourth revolution adding connectivity of all applications and systems over the internet, made possible by the availability of tools like networks, sensoring and IoT. Mass production of all similar objects is complemented with mass customized production, individualizing each item. The Fourth Industrial Revolution is a way of fusion of advances in artificial intelligence (AI), robotics, the Internet of Things (IoT), 3D printing, genetic engineering, quantum computing, BIM (Building Information Modelling), and other technologies. It's the collective force behind many products and services that are fast becoming indispensable to modern life. It is defined as a set of technologies and concepts with the aim of organizing added value, combining Cyber-physical systems (CPS), Internet of Things (IoT) and Internet of Services (Internet of Services, IoS). In contrast to automated production - Computer-integrated Manufacturing, the previous stage of industrial development, "Industry 3.0" - Internet technologies that provide communication between people, machines and products are becoming the central element in the functioning of production systems.

As with any revolution it means that work and organisation of work needs to be tuned with new features. There is a call for a new labour force skilled in computer usage and connecting to (many) different applications, with workers which are flexible in working hours and working places.

The impact on different areas is considerable:

- Economy: investment in technological resources and human resources (staff skilled in new competences)
- Technological challenges: connected technology (networks, IoT, robots, cyber security), new manufacturing technology (Additive manufacturing) and new software solutions (digital twins, machine learning, Artificial intelligence, augmented and virtual reality...).
- Organisational issues: organisation of the combination of work and free time, distant work, empty offices..
- Changing the organisation from a more hierarchic and controlled environment to a decentralized and more individual responsible labour force on the one side, blending in of human labour force with technology (connected labour force, robots).

3 Module Description

3.1 Overall Learning Outcomes

- Students learn the roots of digital transformation towards Industry 4.0 and understand how to overcome the challenges of digital transformation projects.
- Students get knowledge on the key emerging technologies which are at the core of Industry 4.0 in order to have them understand what the technological challenges are for a digital transformation towards Industry 4.0.

- Students learn about the consequences of the process of introduction of Industry 4.0 into an organisation: the change management and effects on project management.
- Students can propose argumented steps to be taken to implement digital transformation (technologies, project management techniques) in an industry 4.0 setting.

3.2 Target Group Analysis

Target groups consist out of students (bachelor/master), professionals from industry (Life Long Learning) and academic staff.

Their needs of each target group is described in Table 1.

Table 1: Target group analysis

	Prerequisite	Current position	Needs	Prospective Job Field
Master level student	Bachelor in technology domains (IT, Engineering) Technological knowledge on software/computational thinking, on technology (general), on electronics, on basic knowledge on office applications,	Student	• gain knowledge on technologies of the 21st century • see the interrelations between technologies and the connections to existing industrial installations/machines/plants in order to understand how projects will span and connect a whole range of different applications. And as such demand for a more helicopter view.	Master level position in engineering or design sectors. Position as project manager.
Lifelong learning student	Bachelor/Master in technology domains (IT, Engineering) or equivalent experience	Professional	• Trained in specific courses of the module on new technologies. • External motivation to keep on learning (motivation to dedicate to the module may be hindered by other factors such as work deadlines, family tasks...).	Improvement of position in current or new organisation. update of knowledge to be able to function in digital transformed organisation

Academic Staff	Technological knowledge on software/computational thinking, on technology (general), on electronics, on basic knowledge on office applications,	Teacher	To have in depth knowledge on technologies of the 21st century, being able to make connections between technologies and to existing industrial installations/machines/plants in order to understand how projects will span and connect a whole range of different applications. Being able to guide the digital transformation towards an interconnected environment.	

3.3 Competences & Learning Outcomes

3.3.1 Module course "Introduction to Industry 4.0 and pathways to Industry 4.0 project management" (Core course, obligatory)

Knowledge:

- Student will learn the roots of digital transformation towards Industry 4.0.
- Student understands how to overcome the challenges of digital transformation projects.
- Student will have knowledge about real cases from different industries
- Student will have knowledge about business and organization demands related to industry 4.0
- Student will outline challenges of organization to deal with Industry 4.0
- Student will have knowledge of the management processes that Industry 4.0 projects require

Skills:

- Student will be able to integrate the knowledge about industry evolution towards industry 4.0
- Student is able to utilise tools and techniques of project management in Industry 4.0 projects.
- Student can analyze the projects in industry 4.0
- Student can utilise financial systems needed for industry 4.0

General competences:

- Student is able to describe the challenges that Industry 4.0 can address
- Student is able to enumerate the main technolologies related to Industry 4.0
- Students will be able to monitor work processes related to project and finance management in Industry 4.0

3.3.2 Module technical course "Digital Twins" (Technical course: elective)

Knowledge:

- Student will have a general understanding of the digital twins concept and can give examples of its applications.
- Student will have knowledge of the implementation processes for Digital twin systems starting from design to implementation on a physical system.
- Student can explain the structure of cyber-physical systems in the digital twin context.
- Student can detect and select the different sensors and actuators in the cyber-physical system.

Skills:

- Student will be trained on a digital twin software.
- Student can specify the elements for the use of a digital twin in a specified technical field
- Student will have the ability to think critically when interpreting simulation data from the digital twin

General competences:

- Student is able to convert data into information that gives value in the process of decision-making in the management process.
- Student has a critical and analytical approach to decision making for the development of solutions in Cyber-Physical systems.

3.3.3 Module technical course "IoT" (Internet of Things) (Technical course: elective)

Knowledge:

- Student understands what constitutes an IoT design solution
- Student can explain the component parts of an IoT network and its connections
- Student recognizes and can name the software and hardware needs of an IoT project
- Student can explain how data is managed in an IoT network

Skills:

- Student can identify the sensors and other devices needed for different IoT solutions
- Student can make a basic electronic design as applied to IoT sensors and embedded controllers
- Student can map out an IoT system incorporating specific devices
- Student can analyse protocols and determine best fit for different IoT applications

General competences:

- Student can evaluate different infrastructure components and network systems
- Student gains a deep appreciation of IoT-solutions and can brainstorm about IoT ideas within specific areas of expertise

3.3.4 Module technical course "Additive manufacturing" (Technical course: elective)

Knowledge:

- Student acquires the vocabulary necessary to navigate the complex landscape of additive manufacturing equipment, materials, and applications.

- Student understands the fundamental principles and workflow for AM of polymers, resins, and metals, and how these principles govern the performance and limitations of each mainstream AM process.

Skills:

- Student learns to identify how, when, and where AM can create value across the entire product lifecycle, from design concepts to end-of-life
- Student knows how to select an AM process and material for a specific application.
- Student is trained in the skills necessary to design parts for AM that combine engineering intuition with computationally-driven design and process-specific constraints.

General competences:

- Student can assess the value of an additively manufactured part based on its production cost and performance.
- Student can estimate the business case for transitioning a product to be made using AM versus the conventional approach, either in part or in whole.

3.3.5 Module BIM (Building Information Modelling)

Knowledge:

- Digital twin in civil engineering: how to define the needed LOD (Level of Development);
- How to deal with an iterative design process and/or modifications during the design/production process;
- Why to use a digital platform to communicate between stakeholders.

Knowledge:

- Student acquires the vocabulary related to BIM processes (content and management)
- Student can translate the processes/ phases in design of buildings into BIM requirements (LOD)

Skills:

- Student learns how to communicate efficiently by means of a BIM model
- Student is able to add efficiency in the model using international BIM standards (ILS)
- Student is able to implement a BIM protocol and BIM execution plan

General competences:

- Student can setup a simple BIM process.
- Student can communicate technical information in a BIM process

3.3.6 Module technical course "Quality of industrial systems/predictive maintenance/condition monitoring" (Technical course: elective)

Knowledge:

- students will learn theoretical material for development of the development of the dependable industrial systems
- students will understand the challenges of industrial IoT systems and techniques to solve them
- students will learn the eMaintenance solutions

Skills:

- Students will be able to implement the ML methods for predictive maintenance in intelligent manufacturing systems

General competences:

- Students will be able to implement variery of methods and techniques within the product life cycle to ensure high quality of products and processes

3.3.7 Module technical course "Data analysis for industry 4.0/Use of Big Data" (Technical course: elective)

Knowledge:

- student acquires data science approach toworkplace and environmental awareness for ergonomics;
- student understands about structuring and examining large amounts of data on complex processes;
- student can explain the design of data and workflow models;
- student understands the role of Big Data analytics in Industry 4.0;

Skills:

- student can to interact with big data tools and and technology;
- student is able to perform Big Data management, use of cloud computing and data storage;
- student will be able to implement Big Data analytics Info-graphics for intuitive and engaging interpretation of data analytics;
- student will be able to implement predictive maintenance systems (sensors, data flows and analytics);
- student knows how to real time management leveraging monitoring and tracking technologies in digital production systems based work 4.0;

General competences:

- Big Data/Data Analytics as combination of big data competency with sensors and mobile technology as well as predictive maintenance and machine learning;
- design and implementation of Big Data architectures and software platforms;
- analysis of Big Data (e.g. sentiment analysis) to predict system behavior and other phenomena impacting the smart production processes.

3.4 Content

The Module M03 Industry 4.0 is conceived as containing 2 compulsory courses:

- Introduction to Industry 4.0 and pathways to Industry 4.0 project management (2 ECTS)
- Industry 4.0 case studies (depending on the context at the partner HEI, can be integrated in the local courses of the module)

And electives on the technical topics (minimum 2 electives)

3.4.1 Core courses:

3.4.1.1 Introduction to Industry 4.0 and pathways to Industry 4.0 project management(2 ECTS)

- Brief history of needs that caused evolution from industry 3.0 towards industry 4.0.
- What are elements of Industry 4.0 and their definitions?
- Industry 4.0 definitions, frameworks, scenarios and applications
- Industrial internet
- Dominant technologies and trends of elements
- Organization and Business interaction with Industry 4.0
- Pathways to Industry 4.0 project management: for project and financial management, benefit management, sustainable , change management
- Project management methods tailoring for industry 4.0 : In this part student will learn about how Industry 4.0 changes the structure of projects; what are tools and techniques that can help to performs projects for industry 4.0, how these tools are used , when it is applicable and why it must be used.
- Business and Organization's Structure tailoring for Industry 4.0: In this part, student will learn what benefits Industry 4.0 will bring to the business or organization. What will be the challenges for adopting industry 4.0 in different structure of business and organization, how to deal with challenges and what are success and failure stories. What sector and disciplines in an organization are affected, are in favor or resistant to use industry 4.0 and how change from industry 3.0 to 4.0 is managed in a Sustainable approach.
- Financial systems tailoring for industry 4.0: In this part student will become familiar with financial services that are beneficial for implementation in industry 4.0; what financial aspects of industry 4.0 are what are the limitations and benefits of different Financial Models in interaction with industry 4.0.

3.4.1.2 Industry 4.0 case studies (In Customs, Projects, Organizations, Universities, etc.) (depending on local context)

3.4.2 Elective courses: Technologies used in Industry 4.0 (2 - 3 ECTS each electives)

3.4.2.1 IoT (NUZP - A. Parkhomenko)

- IoT implementation and standardization
- Wireless and cloud technologies as the basis of the IoT concept
- Assessing and selecting a cloud platform for running IoT application

3.4.2.2 Digital Twins (KU Leuven P.Arras)

- The concept of modelling and virtual representations of physical worlds
- Measurement and data generation
- Predictive maintenance with Digital Twin
- Characteristics of the physical system to implement digital twin
- Digital communication - Internet of Things

3.4.2.3 Additive Manufacturing (NUZP - A. Parkhomenko)

- Overview of AM categories
- AM process overview with real printed parts
- Additive manufacturing design guidelines
- Topology optimisation
- Part re-design for additive manufacturing

3.4.2.4 "BIM" (Building Information Modelling) (KU Leuven – D. Jansen)

- Digital twin in civil engineering: how to translate model to communication in construction application

3.4.2.5 Quality of industrial systems/predictive maintenance/condition monitoring (NUZP - G. Tabunshchyk)

- Quality of industrial systems
- e-Maintenance
- Predictive maintenance and condition monitoring
- Intelligent predictive maintenance

3.4.2.6 Data analysis for industry 4.0/Use of Big Data (module course from Work4.0 and module of data analysis) (2ECTS) (WUNU Pavlo Bykovyy/Michael Dombrovsky)

- Big Data Analytics for Delivering Intelligence in IIoT System
- Technologies and Algorythms for BDA in IIoT systems
- Framework and tools for BDA
- Tools for data exploration, analysis and visualisation

3.5 Teaching & Learning Activity Plan

3.5.1 Select Teaching/learning methods per competence

The teaching/learning methods is chosen according to the scheme in . Figure 2. This scheme is the guide throughout the Work4Ce project for linking competences to appropriate methods. Using the same scheme gives a unified outlook to all developed courses.

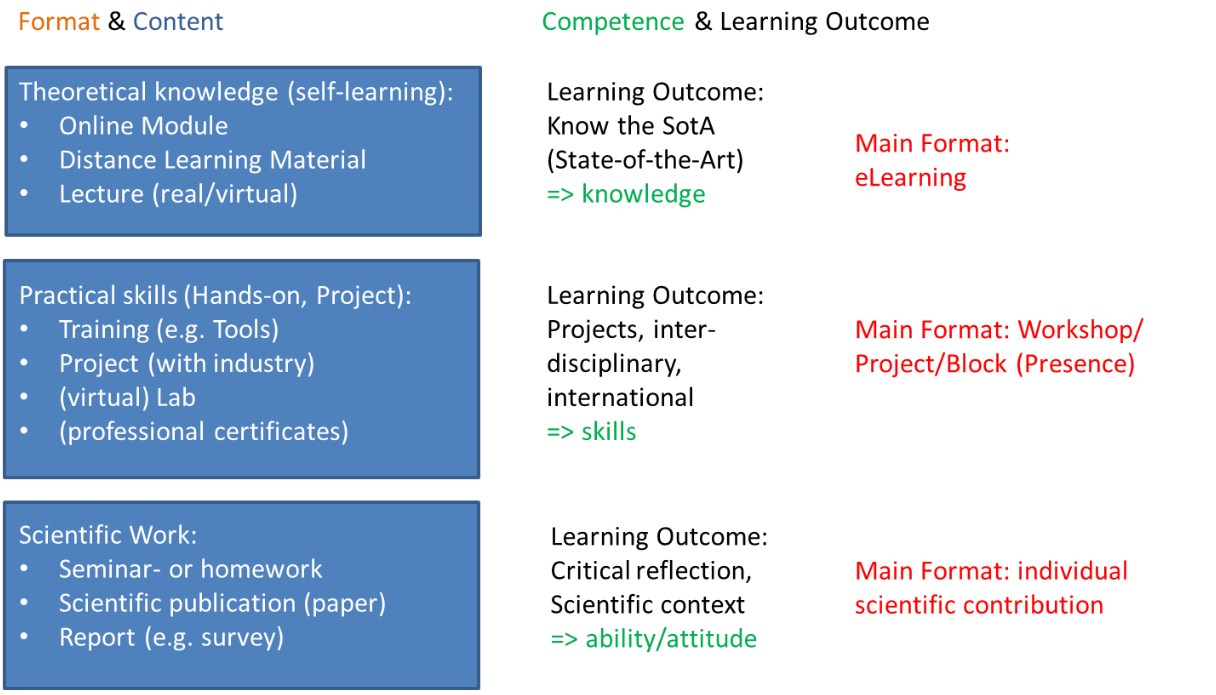

Figure 2 Mapping of Didactic Formats to Competence Areas [own source]

3.5.2 Define didactic concept:

The Module M03 Industry 4.0 is conceived as containing 3 compulsory courses:

- Introduction to Industry 4.0 (2ECTS)
- Consequences and pathways to Industry 4.0 project management (2 ECTS)
- Industry 4.0 case studies (depending on the context at the partner HEI, can be integrated in the local courses of the module)
- And electives on the technical topics (minimum 2 electives)

The core courses are mostly knowledge acquirement: this is achieved via webinars and knowledge clips, complemented with own reading in suggested reference literature.

The electives are all technical courses, which contain a theoretical part which will be taught with the use of webinars and knowledge clips (and local classroom teaching).

For the skills part of the technical courses lab sessions will be used to train hands-on. Labs can be either physical labs, either virtual or remote labs, depending on the course.

For each course a (number of) reference book(s) is given as either compulsory either extra literature.

Most of the lab sessions for the technical course use a problem-based approach.

3.5.3 Define an Activity Plan

The core courses start at the beginning of the semester. The assignments and study of case studies can be delayed till the last weeks of the semester, to integrate the knowledge of the electives/labs.
The electives can run parallel, and depending on the availability of labs, some electives can be concentrated in a block week.

3.5.3.1 Core courses:

Activity 1: Theory classes on **Introduction to Industry 4.0** via webinars, knowledge clips (15 x 2 h = 30 h)

- The theory classes are complemented with online materials and reading materials (selection of papers)

Activity 2: Theory classes on **Consequences and pathways to Industry 4.0 process management via webinars, knowledge clips**

- While role-play games (putting students in an organization and project role and asking them to identify and implement the skills they received.) is very efficient teaching mode. Using digital twin technology in this role-play game would be beneficial

- Homework: writing a project management manual for a project case study (15 h)
  - Students write the manual based on an approved project case study (can be provided by university or submitted by student) and by using a given template for the project manual (e.g. IPMA compliant)

Activity 3: Project simulation in teams (e.g. 3-4 students) => 30 h

- Students conduct the example project outlined in one of the project manuals. Roles are assigned and students produce the relevant project documents and artefacts. A “project kick-off presentation” and a “project end presentation” are provided (each one with 15-20 min presentation time).

- Alternative A for Activity 3: Project internship in a company (1 week)

- Alternative B for Activity 3: Present a project case from own job

3.5.3.2 Electives/technical courses:

3.5.3.2.1 Module technical course "IoT" (Internet of Things)

- **Activity 1:** Theory classes on **Internet of Things** (20 h)
  - The theory classes are complemented with distance learning materials (knowledge clips, reading materials).
  - Homework: reading selected papers.

- **Activity 2:** Lab session on **Internet of Things** (20 h)
  - Students perform lab works in virtual environment to train design and technological skills.
  - Homework: writing a report about performed assignments.

- **Activity 3:** Case-study on **Internet of Things** (20 h)
  - Students conduct activities on an approved case study topic (can be provided by lecturer or submitted by student).
  - Homework: preparing presentation to communicate results and do a scientific discussion and reflection.

3.5.3.2.2 Module technical course "Additive manufacturing"

- **Activity 1:** Theory classes on **Additive manufacturing** (20 h)
  - The theory classes are complemented with distance learning materials (knowledge clips, reading materials).
  - Homework: reading selected papers.

- **Activity 2:** Lab session on **Additive manufacturing** (20 h)
  - Students perform lab works in virtual environment to train design and technological skills.
  - Homework: writing a report about performed assignments.

- **Activity 3:** Case-study on **Additive manufacturing** (20 h)
  - Students conduct activities on an approved case study topic (can be provided by lecturer or submitted by student).
  - Homework: preparing presentation to communicate results and do a scientific discussion and reflection.

3.5.3.2.3 Module technical course "Digital Twins"

- **Activity 1:** Theory classes on **Digital Twins** (24 h)
  - The theory classes are complemented with distance learning materials (knowledge clips, reading materials).
- **Activity 2:** Lab session on **Digital Twins** (20 h)
  - Students perform lab works in virtual environment to train design and technological skills: they make a virtual prototype to instrument and actuate similar to the real object
  - Homework: writing a report about performed assignments.
- **Activity 3:** Case-study on **Digital Twins** (20 h)
  - Students conduct activities on an approved case study topic (can be provided by lecturer or submitted by student).
  - Homework: preparing presentation to communicate results and do a scientific discussion and reflection.

3.5.3.2.4 Module technical course "BIM"

- **Activity 1:** Theory classes on BIM (20h*)
  - The theory classes are complemented with distance learning materials (knowledge clips, reading materials)
- **Activity 2:** Lab session on BIM (20h*)
  - Students perform lab works in virtual environment to train design and technological skills.
  - Homework: writing a report about performed assignments.
- **Activity 3:** Case-study on BIM (20h*)
  - Students conduct activities** on an approved case study topic (can be provided by lecturer or submitted by student).
  - Homework: preparing presentation to communicate results and do a scientific discussion and reflection.

* the number of hours is not fixed yet, nor the ratio between the activities.
** in order to deal with the problems related to the different interests of stakeholders it's an added value to let the students work together

3.5.3.2.5 Module technical course "Quality of industrial systems/predictive maintenance/condition monitoring"

- **Activity 1:** Theory classes (30 h)
  - Organised as online material as video lectures, presentations, reviews of the selected papers.
  - On-line interactive QA sessions after each topic (approximtely each 4 weeks)
- **Activity 2:** Project thesis (30 h) (could be organised jointly with the industry)
  - Students should work on the project in group of 4 students
  - Final presentation of the work

3.6 Teaching & Learning Resources

List all required Literature/Media/Technical Requirements/Lab Equipment
Define Learning Management System (LMS, mandatory: moodle) and other required IT tools

Module technical course "IoT" (Internet of Things)

- software for the learning process (OpenHAB)
- online platforms (Tinkercad, OpenHAB, WOKWI)
- IoT platform (Thinger.io)

Module technical course "Additive manufacturing"

- software for the learning process (e.g. PTC Creo)
- hardware for the learning process (e.g. 3D printer).

Module technical course "Digital Twins"

- software to build virtual prototype/digital twins (e.g. PTC Creo, Siemens NX, Autodesk Inventor, Simulink)
- actuators and sensors to instrument the physical model

Module technical course "BIM"

- software to build virtual prototype/digital twins (Autodesk REVIT)
- online platform to share digital information (google drive, Microsoft Onedrive,...)

3.7 Tailoring & Educational Tracks

Educational Tracks:

- students: take all core courses and 2-3 electives
- professionals/life long learning students: take core courses + case studies + (min) 1 elective in the area of their own job-related field.

3.8 Assessment Methods

All assessment and results are stored in a personal portfolio.

Core courses:

Table 2: Assesment methods for core courses

FORM	%	REMARK
Written exam	30	Based on theory classes
Homework: *writing a project management case for industry 4.0*	30	
Team presentation 1 for project simulation	20	Project kick-off presentation
Team presentation 2 for project simulation	20	Project end presentation

Elective courses: (all electives use the assessment method underneath)

Table 3: Assesment methods for elective courses

FORM	%	REMARK
Written exam	40	Based on theory classes
Homework: *writing a report on the lab activities*	30	
Evaluation of lab activities	20	permanent evaluation
Team presentation for results discussion	10	Project end presentation

3.9 Curricula Integration

Integration in degree studies:

- For engineering studies: with extra technical electives
- For project management studies: bigger amount of cause studies

3.10 Quality Assurance - Evaluation

3.10.1 Quality assurance

Describe how the quality of the module will be assessed in combination with the foreseen didactical concept for the module.

When and how quality of the module is tested.

- When: after each lesson, after the course, meanwhile
- How: surveys, portfolio, logbook

3.10.2 Evaluation

Evaluation depends on the course:

- Core courses:
- Elective technical courses: exam assessment and/or lab-project presentation.

Describe the evaluation of the quality and actions to be taken/improvements:

- To improve student learning (e.g. other activating learning methods)
- To improve the teaching process (e.g more/less asynchronous learning (clips/movies), more/less projectized assignments, general or personal feedback sessions…)
- To improve the content/materials (e.g. more specialized on some topics, more clips, more e_learning, physical written materials.…)

4 Syllabus/Module Handbook

Entry for the Syllabus/Module Handbook

Industry 4.0 (MOD-I40)						
Module Owner KU Leuven	**Workload** 200 h, Foreseen 25-30hours/credit	**Credits** 4 core ECTS min 2*2 ECTS electives	**Semester**	**Frequency** *1*	**Duration** 1 Semester	
1	**Course Title** Digital transformation Industry 4.0	**Contact hours** 4 hours per week / 60 h in total	**Self-Study** 120 h	**Planned Group Size** 25 students		
2	**Course Description** The Module M03 Industry 4.0 is conceived as containing 2 compulsary courses: • Introduction to Industry 4.0 and pathways to Industry 4.0 project management (2 ECTS) • Industry 4.0 case studies (depending on the context at the partner HEI, can be integrated in the local courses of the module) And electives on the technical topics (minimum 2 electives)					

3	**Course Structure**
	
	• Introduction to Industry 4.0 and pathways to Industry 4.0 project management (4ECTS)
	  ○ Brief history of needs that caused evolution from industry 3.0 towards industry 4.0.
	  ○ What are elements of Industry 4.0 and their definitions?
	  ○ Industry 4.0 definitions, frameworks, scenarios and applications
	  ○ Dominant technologies and trends of elements
	  ○ Organization and Business interaction with Industry 4.0
	  ○ Pathways for project and financial management, benefit management, sustainable , change management
	  ○ Project management methods tailoring for industry 4.0 : In this part student will learn about how Industry 4.0 changes the structure of projects; what are tools and techniques that can help to performs projects for industry 4.0, how these tools are used , when it is applicable and why it must be used.
	  ○ Business and Organization's Structure tailoring for Industry 4.0: In this part, student will learn what benefits Industry 4.0 will bring to the business or organization. What will be the challenges for adopting industry 4.0 in different structure of business and organization, how to deal with challenges and what are success and failure stories. What sector and disciplines in an organization are affected, are in favor or resistant to use industry 4.0 and how change from industry 3.0 to 4.0 is managed in a Sustainable approach.
	  ○ Financial systems tailoring for industry 4.0: In this part student will become familiar with financial services that are beneficial for implementation in industry 4.0; what financial aspects of industry 4.0 are what are the limitations and benefits of different Financial Models in interaction with industry 4.0.
	• Technologies used in Industry 4.0
	  ○ IoT (2ECTS)
	    ▪ IoT implementation and standartization
	    ▪ Wireless and cloud technologies as the basis of the IoT concept
	    ▪ Assessing and selecting a cloud platform for running IoT application
	  ○ Digital Twins (2ECTS)
	    ▪ The concept of modelling and virtual representations of physical worlds
	    ▪ Measurement and data generation
	    ▪ Predictive maintenance with Digital Twin
	    ▪ Characteristics of the physical system to implement digital twin
	    ▪ Digital communication - Internet of Things
	  ○ Additive Manufacturing (2ECTS)
	    ▪ Overview of AM categories
	    ▪ AM process overview with real printed parts
	    ▪ Additive manufacturing design guidelines
	    ▪ Topology optimisation
	    ▪ Part re-design for additive manufacturing
	  ○ Quality of industrial systems/predictive maintenance/condition monitoring (2ECTS)
	    ▪ Quality of industrial systems
	    ▪ eMaintanance
	    ▪ Predictive maintenance and condition monitoring
	    ▪ Intelligent PDM

	◦ Data analysis for industry 4.0 (2ECTS) ▪ Big Data Analytics for Delivering Intelligence in IIoT System ▪ Technologies and Algorythms for BDA in IIoT systems ▪ Framework and tools for BDA ◦ BIM (Building Information Modeling) ▪ Digital twins in civil engineering ▪ Standards and norms for BIM ▪ Dealing with an iterative design process and/or modifications during the design/production process; ▪ Digital platforms to communicate between stakeholders. ▪ Case study: BIM in Autodesk Revit. • Industry 4.0 case studies (In Customs, Projects, Organizations, Universities, etc.)
4	**Application Focus** The Industry 4.0 module aims at bringing the students the introduction knowledge on the key emerging technologies which are the core of Industry 4.0 in order to have them understand what the technological challenges are for a digital transformation towards Industry 4.0. After an introduction on the history of industrialisation, with the differences and enhancements of each of the different industrial revolutions, the core of the module is a more in depth exploration of the key technologies of Industry 4.0. After the description of Industry 4.0 and the technologies, the modules takes in consideration the consequences of the industry 4.0 revolution (change management) on the organisation of work, of the organisations, of the economic impact and of the technological switch the organisations have to make or will undergo.
5	**Scientific Focus** Scientific focus is on the consequences of the implementation of industry 4.0 technologies on the organisation of project management.

6	**Parameters summary:**
	
	• ECTS: 8 (2 ECTS for introduction and consequences) (2 for each elective technology course)
	• Hours of study load in total: 200
	• Weekly hours per semester: 4
	  ○ Contact hours: 60
	  ○ Self-Study hours: 140
	
	• Course characteristics:
	  ○ Core part (compulsary): introduction and consequences
	  ○ Electives: course modules on technology: students should take at least 2 elective courses for a minimum of 4 ECTS
	• Course frequency: every year - semester 2
	• Maximal capacity: 25 students (elective courses are limited by seats in the lab-sessions)
	• Course admittance prerequisites:
	  ○ for introduction and consequenties: none
	  ○ for technological electives: depending on the elective
	• Skills trained in this course: theoretical, practical and scientific skills and competences
	• Assessment of the course: contributions within case study project (team presentation) (50%) and written paper (literature review, report or survey, approx. 25 pages) and presentation (in class or at a student conference, e.g. XXX (PM Kiev)) (50%)
	• Teaching staff: teachers from Open Community of Practice

7	**Learning outcomes** **7.1 Module course "Introduction to Industry 4.0 and pathways to Industry 4.0 project management" (Core course, obligatory)** *Knowledge:* • Student will learn the roots of digital transformation towards Industry 4.0. • Student understands how to overcome the challenges of digital transformation projects. • Students have have knowledge about real cases from different industries • Student have knowledge about business and organization demands related to industry 4.0 • Student will outline challenges of organization to deal with Industry 4.0 • Students will have knowledge of the management processes that Industry 4.0 projects require *Skills:* • Student will be able to integrate the knowledge about industry evolution towards industry 4.0 • Student is able to utilise tools and techniques of project management in Industry 4.0 projects. • Student can analyze the projects in industry 4.0 • Student can utilise financial systems needed for industry 4.0 *General competences:* • Student is able to describe the challenges that Industry 4.0 can address • Student is able to enumerate the main technolologies related to Industry 4.0 • Students will be able to monitor work processes related to project and finance management in Industry 4.0 **7.2 Module technical course "Digital Twins" (Technical course: elective)** *Knowledge:* • Student will have a general understanding of the digital twins concept and can give examples of its applications. • Student will have knowledge of the implementation processes for Digital twin systems starting from design to implementation on a physical system. • Student can explain the structure of cyber-physical systems in the digital twin context. • Student can detect and select the different sensors and actuators in the cyber-physical system. *Skills:* • Student will be trained on a digital twin software. • Student can specify the elements for the use of a digital twin in a specified technical field • Student have the ability to think critically when interpreting simulation data from the digital twin

General competences:

- Student is able to convert data into information that gives value in the process of decision-making in the management process.
- Student has a critical and analytical approach to decision making for the development of solutions in Cyber-Physical systems.

7.3 Module technical course "IoT" (Internet of Things) (Technical course: elective)

Knowledge:

- Student understands what constitutes an IoT design solution
- Student can explain the component parts of an IoT network and its connections
- Student recognizes and can name the software and hardware needs of an IoT project
- Student can explain how data is managed in an IoT network

Skills:

- Student can identify the sensors and other devices needed for different IoT solutions
- Student can make a basic electronic design as applied to IoT sensors and embedded controllers
- Student can map out an IoT system incorporating specific devices
- Student can analyse protocols and determine best fit for different IoT applications

General competences:

- Student can evaluate different infrastructure components and network systems
- Student gains a deep appreciation of IoT-solutions and can brainstorm about IoT ideas within specific areas of expertise

7.4 Module technical course "Additive manufacturing" (Technical course: elective)

Knowledge:

- Student acquires the vocabulary necessary to navigate the complex landscape of additive manufacturing equipment, materials, and applications.
- Student understands the fundamental principles and workflow for AM of polymers, resins, and metals, and how these principles govern the performance and limitations of each mainstream AM process.

Skills:

- Student learns to identify how, when, and where AM can create value across the entire product lifecycle, from design concepts to end-of-life
- Student knows how to select an AM process and material for a specific application.

- Student is trained in the skills necessary to design parts for AM that combine engineering intuition with computationally-driven design and process-specific constraints.

General competences:

- Student can assess the value of an additively manufactured part based on its production cost and performance.
- Student can estimate the business case for transitioning a product to be made using AM versus the conventional approach, either in part or in whole.

7.5 Module BIM (Building Information Modelling)

Knowledge:

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    - Student acquires the vocabulary related to BIM processes (content and management)
    - Student can translate the processes/ phases in design of buildings into BIM requirements (LOD)
    -

Skills:

- Student is learns how to communicate efficiently by means of a BIM model
- Student is able to add efficiency in the model using international BIM standards (ILS)
- Student is able to implement a BIM protocol and BIM execution plan

General competences:

- Student can setup a simple BIM process.
- Student can communicate technical information in a BIM process

7.6 Module technical course "Quality of industrial systems/predictive maintenance/condition monitoring" (Technical course: elective)

Knowledge:

- students will learn theoretical matherial for development of the development of the dependable industrial systems
- students will understand the challenges of industrial IoT systems and tech-niques to solve them
- students will learn the eMaintenance solutions

Skills:

- Students will be able to implement the ML methods for predictive maintenance in intelligent manufacturing systems

	General competences: • Students will be able to implement variety of methods and techniques within the product life cycle to ensure high quality of products and processes
8	**Teaching and training methods** • Core: Introduction: lectures (webinars, knowledge clips) introducing concepts, own literature reading • Core: Consequences: for project and financial management, benefit management, sustainable , change management: lectures (webinars, knowledge clips) to teach knowledge, project work in block weeks/hackathon format to implement. While role-play games (putting students in an organization and project role and asking them to identify and implement the skills they received.) is very efficient teaching mode. Using digital twin technology in this role-play game would be beneficial. • Electives: Technologies used in Industry 4.0: lectures (webinars, knowledge clips) to teach knowledge, lab sessions (physical and remote labs) to train technological skills • Presentations to communicate results and do a scientific discussion and reflection
9	**Curricula Integration** Integration in degree studies: • For engineering studies: with extra technical electives • For project management studies: bigger amount of case studies

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