PLANET

Practical Learning
of Artificial Intelligence
on the Edge for indusTry 4.0

R5.4 HANDBOOK ON HOW TO ORGANIZE AND IMPLEMENT AN "ML ON THE EDGE 4.0" TRAINING COURSE

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EXECUTIVE SUMMARY

This document is aimed to provide a comprehensive guide for implementing and replicating the PLANET4 training course in other non-partner institutions. It contains a general overview of the course layout, detailed guidelines on how to replicate the training model, including learning methodologies, expected learning outcomes, assessment techniques, tips on organizational tasks, and guidelines for monitoring and evaluation. This document needs to be considered together with all the training materials and evaluation tools available on the PLANET4 website. By following the guidelines outlined in this document and using the developed training materials, institutions shall be able to successfully implement the PLANET4 course and achieve the desired learning outcomes.

COURSE OVERVIEW

Course Organization

The overall goal of the PLANET4 course is to provide an effective training on the hard and soft skills necessary required by professionals to add value in Industry 4.0 scenarios. In this regard, the course is articulated into three Teaching Areas:

1. Teaching Area 1: Fundamentals of Industry 4.0. This unit introduces the Industry 4.0 concept and provides a training on the fundamentals of its enabling technologies: artificial intelligence, cloud and edge computing, and Internet of Things.
2. Teaching Area 2: Innovation and Change Management. This unit provides a training on the required soft skills to add value in Industry 4.0 scenarios: collaboration in multidisciplinary teams, human-centered design and lean strategies, fast pretotyping.
3. Teaching Area 3: How to solve Industry 4.0 challenges. This unit provides a hands-on training on how to identify and analyze industrial needs, propose feasible technological solutions to solve industrial challenges, and appropriately structure the proposed solutions.

Expected Learning Outcomes

The expected Learning Outcomes to be gained by the students upon the completion of the course are the following:

LO1. Students will be able to define Industry 4.0 and explain its impact on the manufacturing industry and society.

LO2. Students will have a solid understanding of the enabling technologies of Industry 4.0, including artificial intelligence, cloud and edge computing, and Internet of Things.

LO3. Students will be able to use data mining and analysis tools to extract insights from large datasets and make data-driven decisions for Industry 4.0 environments.

LO4. Students will be able to understand the challenges on designing and implementing cloud-based and local-based (i.e., edge-based) automated solutions to optimize production systems and other industrial processes.

LO5. Students will have a good understanding of IoT and IIoT technologies and their applications in Industry 4.0.

LO6. Students will be able to identify and analyze industrial needs, propose a fast prototypal way to test solutions to solve industrial challenges, and appropriately structure the proposed ideas.

LO7. Students will have the soft skills necessary to add value in Industry 4.0 scenarios, including collaboration in multidisciplinary teams, applying human-centered design, and using lean strategies to propose innovative solutions.

Syllabus Overview

The course is organized into 30 lectures (also referred to as lessons):

Teaching area	Topic	Lesson
Fundamentals of Industry 4.0	Introduction to I4.0	Lesson 1 – Course Introduction
		Lesson 2 – Industry 4.0
		Lesson 3 – The impact of I4.0
		Lesson 4 – Presentation of the tools supporting the course
	Data Science, Artificial Intelligence and Machine Learning	Lesson 5 – Introduction to DS, AI and ML
		Lesson 6 – Cross Industry Process for Data Mining
		Lesson 7 – Machine Learning
		Lesson 8 – Cloud-based and Local-based automated solutions
		Lesson 9 – Real-world use cases
	Internet of Things and Industrial IoT	Lesson 10 – Introduction to IoT and IIoT
		Lesson 11 – Production systems
		Lesson 12 – IIoT systems
		Lesson 13 – Communication protocols
		Lesson 14 – Development areas directions
	Cloud and Edge Computing	Lesson 15 – Introduction to Cloud and Edge Computing
		Lesson 16 – Cloud providers and their associated services
		Lesson 17 – Edge Computing
		Lesson 18 – Real-world use cases
		Lesson 19 – Development areas directions
Innovation and Change Management	Innovation and the product	Lesson 20 – Introduction to the module and Topic lecture
	Design Thinking	Lesson 21 – Assignment review
		Lesson 22 – Topic lecture
	Human Centered Design	Lesson 23 – Assignment review
		Lesson 24 – Topic lecture
	Pretotyping	Lesson 25 – Assignment review
		Lesson 26 – Topic lecture
	Final presentation	Lesson 27 – Final presentation review
How to solve I4.0 challenges	Individual challenge	Lesson 28 – Introduction to the challenges and examples of best practices
		Lesson 29 – Individual challenges presentation and review
	Team challenge	Lesson 30 – Team challenges presentation and review by company experts

A breakdown on how each learning outcome is connected to the lessons of the course is detailed in what follows:

- LO1 is addressed in Lessons 2 and 3, which cover the concept of Industry 4.0 and its impact on various industries and society.

- LO2 is addressed in Lessons 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16, 17, 18, and 19, which cover the various enabling technologies of Industry 4.0, including data science, machine learning, cloud and edge computing, and IoT.
- LO3 is addressed in Lessons 5, 6, 7, 8, and 9, which cover data mining and analysis tools, and their applications in Industry 4.0 environments.
- LO4 is addressed in Lessons 8, 15, 16, 17, 18, and 19, which cover the design and implementation of cloud-based and local-based automated solutions for various industrial processes.
- LO5 is addressed in Lessons 10, 11, 12, 13, and 14, which cover the concepts and applications of IoT and IIoT technologies in Industry 4.0.
- LO6 is addressed in Lesson 3, which covers how to identify and analyze industrial needs, Lessons 9, 14, and 19 that review existing real-world solutions, and Lessons 20, 21, 22, 23, 24, 25, 26, 27, 28, and 29, which cover how to propose and test solutions for industrial challenges.
- LO7 is addressed in Lessons 2, 3, 20, 21, 22, 23, 24, 28, and 30, which cover the importance of collaboration, human-centered design, and lean strategies in Industry 4.0 scenarios.

COURSE IMPLEMENTATION

Learning Methodology

The course is designed to be used using the blended learning methodology, which combines traditional in-presence teaching with online learning activities. This methodology provides a flexible and highly customizable that combines the benefits of both face-to-face and online learning in terms of students' engagement and effective contents delivery. In this regard, each Teaching Area uses different learning methodologies and activities:

- Teaching Area 1: Fundamentals of Industry 4.0 (Lessons 1 – 19): These lessons have been designed to be implemented using the **self-paced learning** methodology. That is, all the course materials (i.e., video-lectures, supporting documents, assignments, assessment activities) to this Teaching Area are available for students and delivered through an e-learning environment (e.g., Moodle) so they can be asynchronously consumed at their own time according to their own needs, learning styles, and preferences. To accommodate students with diverse backgrounds and learning styles in the course, using this methodology in the initial part of the course allows for a more personalized approach, giving students the freedom to spend extra time on concepts they find more challenging and progress more quickly through topics they find easier.
- Teaching Area 2: Innovation and Change Management (Lessons 20 – 27): These lessons have been designed to be implemented using the **flipped-classroom** methodology. In this way, the traditional roles of classroom activities and homework are reversed so students are assigned to watch or read instructional materials (such as videos, articles, or podcasts) prior to class, which frees up class time for more interactive and collaborative activities, such as group discussions, problem-solving exercises, and projects. The contents designed for this Teaching Area have been designed to be delivered in either online (i.e., e-learning) or in-presence scenarios.
- Teaching Area 3: How to solve Industry 4.0 challenges (Lessons 28 – 30): These lessons challenge students to conduct brainstorming sessions and hands-on activities exploiting the benefits of teamwork using the **problem-based learning** approach delivered in an in-presence environment.

Therefore, the requirements to successfully implement the PLANET4 course using these methodologies are the following:

1. Setting up a Learning Management System such as Moodle (see https://planet4project.salle.url.edu/ as reference) able to host all the training materials for Teaching Areas 1 and 2.
2. Staff members with an intermediate knowledge about the topics discussed in Teaching Area 2 (i.e., Innovation and the product, Design Thinking, Human Centered Design, Pretotyping) so they can assess the contributions of students.
3. Staff members with an advanced knowledge about the topics discussed in Teaching Area 3 (i.e., solving problems in Industry 4.0 domains) so they can guide and assess the contributions of students.

Assessment activities

The PLANET4 course has been designed to combine different assessment activities in order to best capture students' progress all over the course:

- Teaching Area 1: Fundamentals of Industry 4.0 (Lessons 1 – 19): Each one of these lessons has a **self-assessment test** plus a set of **open-ended questions**. Answers to these open-ended questions can be graded according to their quality, depth, and accuracy.
- Teaching Area 2: Innovation and Change Management (Lessons 20 – 27): This teaching area asks students to solve an assignment for each one of the three topics covered in the teaching area (Design Thinking, Human Centered Design, Pretotyping) that must be delivered in an **oral presentation**. Additionally, a final presentation integrating the previous three presentations is also requested to students. Therefore, the performance of students in this teaching area can be assess through these four oral presentations considering different criteria such as content (depth and accuracy of the information presented, as well as the clarity and organization of the content), delivery (effective use of vocal variety, eye contact, and body language to engage the audience and convey the message), time management (whether the speakers were able to stay within the allotted time and use it effectively to cover all the key points), visual aids (quality and effectiveness of any visual aids used, such as slides, handouts, or props), engagement (how well the speakers engaged the audience and kept their attention throughout the presentation), and/or Q&A (how well the speakers responded to questions from the audience and whether they demonstrated a clear understanding of the topic)
- Teaching Area 3: How to solve Industry 4.0 challenges (Lessons 28 – 30): This Teaching Area asks students to propose a solution to Industry 4.0 challenges first individually, and finally in a collaborative way. Hence, the same assessment procedure used for the **oral presentations** used in Teaching Area 2 can be used.

To track and monitor students' progress and assessment throughout the course, It is recommended to use the same Learning Management System used to host the training materials associated to Teaching Area 1. Typically, this systems have already built modules that greatly ease this task.

Estimated Workload and ECTS Recognition

The estimated workload of each one of the Teaching areas is detailed in what follows:

Teaching area	In-presence hours[1]	Study hours[2]	Overall hours	Comments
Fundamentals of Industry 4.0	19	17	36	Each one of the lessons of this Teaching Area are designed to require 1 hour of workload to be

[1] In-presence hours consider the number of hours that students spend on attending the lectures and/or reading the training materials.

[2] Study hours consider the number of hours that students spend on solving the assignments, conducting assessment activities, and studying the training materials.

				appropriately read. Additionally, each one of the lessons (except lessons 1 and 4) are designed to require 1 extra hour of study time to solve the associated learning activities.
Innovation and Change Management	14	21	35	Each one of the lessons of this Teaching Area are designed to require 2 hours of students' workload (except the first and the last lessons that should last 1 hour). Additionally, lessons 21, 23, and 25 are designed to require 7 extra hours of study time to solve the associated learning activities.
How to solve Industry 4.0 challenges	7	21	28	The hands-on activities associated to this Teaching Area force students to spend a lot of time out of the regular hours.

It can be seen that the whole PLANET4 course estimates 99 hours of students' effort to successfully meet the expected learning objectives. Considering that 60 ECTS[3] are the equivalent of a full year of study or work (https://education.ec.europa.eu/education-levels/higher-education/inclusive-and-connected-higher-education/european-credit-transfer-and-accumulation-system), 1 ECTS falls in the range of the 25-30 hours. Thus, students enrolled in the PLANET4 course that successfully pass all the assessment activities shall be recognized with 3-4 ECTS.

Proposed course organization for its implementation

The PLANET4 course was created with the intention of being adaptable to various learning environments and easily replicable by universities that are not partners in the PLANET4 consortium. As a result, there is a great deal of flexibility when it comes to organizing and implementing the course materials, whether in full (i.e., the three Teaching Areas) or in part (i.e., some Teaching Areas or even some lessons). The course's Teaching Areas have been designed to be self-sufficient and autonomous, making it possible for other universities to reuse them with very little (or no) effort on decoupling them from the reminder of the course. Also, this gives a high flexibility on the order in which contents are delivered to students.

Nevertheless, there is a logical order for the contents' organization. That is, the course shall start with the Fundamentals of Industry 4.0, continue with the Innovation and Change Management Teaching Area, and finish by putting everything together Solving Industry 4.0 Challenges.

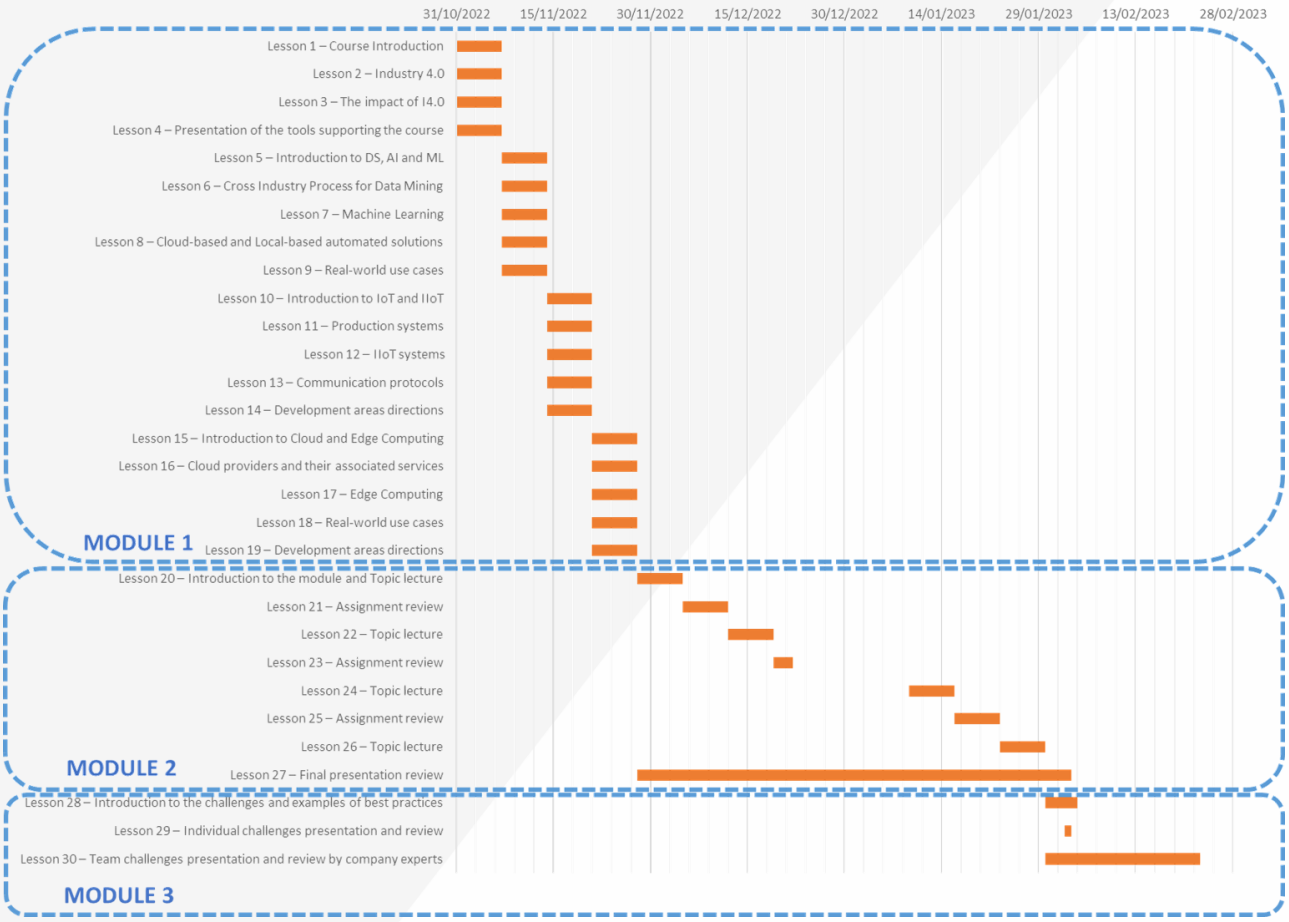
As far as the first Teaching Area is concerned, it can be grouped into 4 knowledge modules: Introduction to Industry 4.0 (Lessons 1-4), Artificial Intelligence and Machine Learning (Lessons 5-9), Industrial Internet of Things (Lessons 10-14), and Cloud and Edge Computing (Lessons 15-19). While the first module should precede the other ones, the last three modules can be implemented either sequentially (no matter their order) or in parallel. During the pilot course, we saw that allowing students to take the three modules in parallel was a little bit overwhelming for them (i.e., they seemed a little bit scared on the amount of work that had to face at a time). Therefore, we suggest to implement these modules sequentially.

[3] European Credit Transfer and accumulation System

As far as the second Teaching Area is concerned, it can be grouped into 5 knowledge modules: Innovation and the product (Lessons 20-21), Design Thinking (Lessons 22-23), Human Centered Design (Lessons 24-25), Pretotyping (Lesson 26), Final presentation (Lesson 27). As these knowledge modules are cumulative, it is strongly suggested to implement them in a sequential order. It is worth noting that this Final Presentation (Lesson 27) will integrate the developments carried during the whole Teaching Area.

Finally, as far as the third Teaching Area is concerned, it is advised that students firstly face the challenge solving individually and later they can export what they have learnt in the team challenge solving.

The following figure depicts a proposed Gantt diagram for the implementation of the whole PLANET4 course:



It is worth noting that (1) Module 2 has been interrupted by Christmas holidays, and (2) both challenges (individual and team) of Teaching Area 3 have been made available to students at the same time. In this way, students can think on how they are going to reuse what they are learning in the individual challenge for the team challenge. Note that the execution of the team challenge should start right after the delivery of the individual challenge.

ORGANIZATION OF TRAINING MATERIALS

Teaching Area 1: Fundamentals of Industry 4.0

Each one of the lessons of Teaching Area 1 has a dedicated folder with the following documents:

- Learning guide: It contains an introduction to the topic, a list of the specific learning objectives of the lesson, the instructions and tasks to be carried for its appropriate development, and a set of open-ended questions. The information listed in this document should be included on the e-learning platform.
- Document with a link to the video-lectures: Each lesson has been split into 15 minutes learning pills in order to keep students engaged to the course. Therefore, for each lesson there is a document with a link to a set of 15 minutes video pills. These video pills shall be embedded to the e-learning platform as well.
- Supporting ppt slides: Each video pill has a supporting ppt document with the slides displayed in the video pill. These slides shall be uploaded to the e-learning platform too.
- Self-assessment test: Each lesson has an associated test (solutions to the test are also included in the Excel file). This test shall be uploaded to the e-learning platform as well and students should be able to access it only once they finish the visualization of the training materials (video pills, slides) and the completion of the learning activities of the learning guide (e.g., open-ended questions).

Teaching Area 2: Innovation and Change Management

This Teaching Area is provided in 2 versions, depending on the choice of teaching modality:

1. A full version embedded in a SCRUM package, in case teachers choose to deliver the lessons of this Teaching Area by having only the group presentations in synchronous mode. This version is recommended for a delivery of the Teaching Area partially on the Moodle platform, reserving time for in-person or online meetings for presentations only. In this version, students must answer questions at the end of each lecture.
2. Supporting ppt slides, if the teachers choose to deliver the “teaching” part of this Teaching Area in presence after each groups presentation.

Teaching Area 3: How to Solve Industry 4.0 Challenges

This Teaching Area is composed by three main components:

- Training materials: in the format of a single ppt slide file to introduce students to the activities to be carried out during this Teaching Area.

- PLANET4 Challenges Templates: a list of challenges presented in the form of a template for students to complete during the activities in this Teaching Area. These challenges were mostly collected from companies in real scenarios (8), while the others were extracted from the literature. The templates are divided into 3 sections, "The Challenge," "Research Phase," and "Proposed Solution." Students are asked to fill out the second and third sections.
- PLANET4 Taxonomy Explorer: the website that students will use as one of the main tools during the model search phase. Using the taxonomy, students will be able to better understand and identify the type of challenge they need to solve, what technologies can address it, and how others have solved similar problems in the literature.
- PLANET4 best practices: a list of already solved challenges is given in their respective templates. They were solved during the development of the course by experts and thus serve as best practices to guide students in correctly filling out the template.

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