MAESTRO

Manufacturing Education for a Sustainable fourth Industrial Revolution

Project No 2019-1-SE01-KA203-060572

Output 3

Development of constructively aligned courses in the domain of Industry 4.0

2019-2022

Co-funded by the Erasmus+ Programme of the European Union

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Cite as: *Maffei A. et al., (2022) Development of constructively aligned courses in the domain of Industry 4.0. MAESTRO: Manufacturing Education for a Sustainable fourth Industrial Revolution. Project No 2019-1-SE01-KA203-060572. Available at: https://maestro.w.prz.edu.pl/project-outputs*

Project Partners

Summary

Funded by the European Union

Document heading

Project title:	**Manufacturing Education for a Sustainable fourth Industrial Revolution**
Output number:	**O3**
Leading organization:	**KTH Royal Institute of Technology**
Output title:	**Development of constructively aligned courses in the domain of Industry 4.0**
Authors:	**KTH Royal Institute of technology with input from the entire consortium**

Intellectual Output 3 as seen in the proposal:

Output Description

This activity addresses the identified gap and mismatches by developing learning material for different courses which includes the technologies and applications identified in O1 and organizes them according to the results of O2. Courses will include:

- Specifically designed, up to date, learning content-case studies featuring the existing implementation of industry 4.0 technology in industry
- Specific reference to the sustainability dimension: this is a very specific and innovative requirement in the Maestro initiative.

Each course will be designed and described according to Constructive Alignment (CA).

CA has emerged from the work of John Biggs as outstanding principle for devising effective and efficient pedagogical activities in higher education. In particular, CA builds upon two main concepts: the constructivist understanding of the learning process and the practical need for aligned and outcome-based curricula designing.

CA gives the necessary common framework for sharing educational objectives among different institutions and different teaching methodologies.

Division of work

KTH will lead the work that will include all the partners in relation to their specific technical expertise.

Task 3.1 Design of learning material. This task will develop learning material both theoretical and methodological for each of the suggested technologies. In detail, this activity will be related to define teaching and assessing strategies for the learning outcomes identified in O2

Task 3.2 Design of case studies. This task will develop course material in the form of case studies featuring current industrial implementation that enhance the sustainability of the related industrial operation. This for each of the proposed technologies. In detail, this activity will adapt the identified industrial application to be used as course material for reflective practicing.

Task 3.3. Workshop in constructive alignment. The partner will get reading material and specifically designed workshop (in Stockholm) to acquire or refresh knowledge in CA. This will allow a homogeneous approach to the description and instantiation of courses across different institutions.

The actual workshop (see C1) will be run by KTH following a scheduled project meeting in Poland in October 2020.

Task 3.4. Course development. This task will implement the results from Task 3.1 and Task 3.2.

All the learning material and case studies produced will be described as single, independent educational unit featuring a stated Intended Learning Outcome (ILO), and related Teaching and Learning Activities (TLA) as well as Assessment task (AT). This will include also a set of suggested grading criteria that could be customized to the audiences at different institution.

Intellectual Output 3 implementation

The activity in the Intellectual Output 3 (O3) was on some extent affected by the Covid-19 pandemic. However, thanks to the alternative activities put in place by the consortium this has not impacted negatively the quality of the results. In detail:

- The planned LTT, Learning Teaching and Training, (C1) on Constructive Alignment (CA) was planned as a meeting in presence with intensive course. KTH is the CA expert and responsible for the LTT. Due to Covid-19 pandemic the workshop was converted in an asynchronous on-line activity based on lectures and homework. As it turned out this worked very well because it allowed the partners to spread the effort on a longer period of time and work on their own pace. The success of this approach could be estimated by KTH by comparing it with a similar course that was run in presence and intensively in a previous Erasmus project (TIPHYS - Social Network based doctoral Education on Industry 4.0 -2017-2020 - Project No: 2017-1-SE01-KA203-034524 www.tiphys.eu)
- The Task 3.2 involved working with our industrial partners. However, this was hindered by various restrictions to external cooperation both from academic and industrial side. In view of this the consortium focused on strengthening the activities in the other tasks: special emphasis was given to developing of the learning material for the educational units developed at the hosting university. This change of strategy resulted in a larger set of educational units that will be implemented in O4. From a planned number of 3 MAESTRO will implement 5.

The adaptation of activities to answer the additional constraints posed by the pandemic has caused a prolongation of the planned time for O3 of 2 months: from the planned end on 2021-03-31 the O3 activities finished on 2021-05-31.

Intellectual Output 3 in the context of the Project

O1
- Mapping of the Ind 4.0 enabling technology (E)
- Impact of the technology on SDG from UN

O2
- Selection of promising E to include in engineering curricula with enphasis on SDG
- Suggestion of educational unit to develop

O3
- Additional Input C1: workshop on Constructive Alignment
- Formulation of Educational Units following CA based proposed method

O4
- Implementation of the Educational Unit
- Evaluation and improvement

O5
- Final release of Educational Unit
- Teaching and learning package for sharing the educational units as result of C2

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Results of Intellectual Output 3

The Intellectual Output 3 goal was to develop a series of Educational Units to introduce specific applications of the technological enabler of the fourth industrial revolution (see Table 1) that address improvement on the SDG for UN. The candidate topics from each involved institution were selected during the Intellectual Output 2 and are presented in the Appendix 1.

#	Enabler
1	Internet of Things (IoT)
2	Big Data (BD) & analytics
3	Cloud Computing (CC)
4	Simulation
5	Augmented Reality
6	Additive Manufacturing
7	Horizontal & Vertical System Integration
8	Autonomous Robot
9	Cybersecurity

Table 1 Industry 4.0 technological enabler

The O3 results were produced in parallel with the C1 Workshop on Constructive Alignment held by KTH. The workshop was organized through a series of online lectures where KTH staff introduced the theoretical building blocks of course design using CA as well as showing some examples of implementation. The workshop includes also specific homework consisting of completing aptly devised templates (See Appendix 2). The result of this latter activity is the description of the educational unit that will be presented in the following part of this document.

The approach suggested was articulated in three phases where the partners were asked to develop respectively: the Intended Learning Outcome (hence ILO) and the related Teaching and Learning Activities (hence TLA) and Assessment task (hence AT) for their educational units. All the technical details of the approach can be found by reading the related C1 course material that is based on existing content at KTH and re-adapted for the MAESTRO initiative.

The following Figure 1 details the workflow in O3.

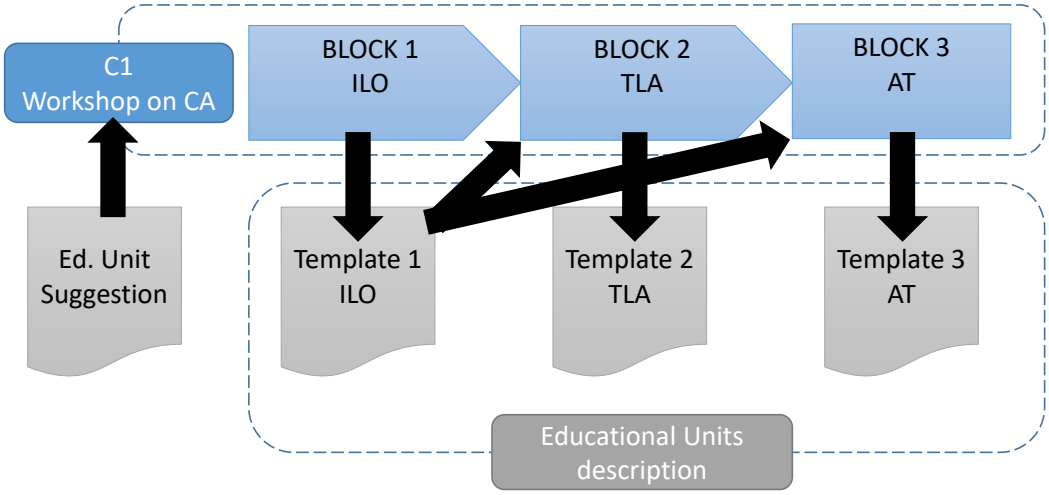

Figure 1 Graphical depiction of O3

In the following sections the produced contributions are presented according to presented layout.

Suggested Intended Learning Outcomes

The template for the formulation of the ILO is emphasizing the student perspective. All the ILO are formulated to address directly what is expected from the learner after following the related educational unit. Three are the key elements:

- Verb: detailing the action expected and referring to the expected level of understanding as expressed in the well-known Bloom taxonomy[1]
- Content to which the action indicated by the verb refer to
- Context where the action for the related content must be applied

KTH –Sweden

Proposal AR and VR for Assembly

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Explain and use suitable AR and VR implementations for assembly on a lean shop floor.	Explain Use	AR and VR implementations	Assembly on a lean shop floor

[1] Bloom, B.S., et al., *Taxonomy of educational objectives: Handbook I: Cognitive domain.* New York: David McKay, 1956. **19**: p. 56.

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PRZ- Poland

Proposal 1 Decision Support System

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	The student shall be able to apply time series analysis techniques to examine the relationship between time series and to search for patterns relevant to support decision-making in the analysed area and interpret the achieved results.	Apply Examine Search Support Interpret	Time series analysis Pattern Results	Decision making

Proposal 2 Lean Manufacturing

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Develop a value stream map taking into account economic, social and environmental aspects.	Develop	Value stream map	Economic, social and environmental
ILO 2	Analyse a current state value stream map taking into account economic, social and environmental aspects	Analyse	Current state of value stream map	Economic, social and environmental
ILO 3	Create a future state of the value stream map taking into account IoT solutions.	Create	Future state of value stream map	IoT solution

Proposal 3 Risk Management

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Develop model of disease spread using System Dynamics method.	Develop	Model of disease spread	System Dynamics
ILO 2	Analyses the simulation results concerning impact of ICT solutions on disease spread and project risk.	Analyses	Simulation of disease spread results	ICT solution and project risk

POLITO – Italy

Proposal 1 Life-Cycle Assessment

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Compare the environmental performance of different manufacturing approaches by modelling their sustainability through Life-Cycle Assessment and other state-of-the-art methodologies.	Compare Model	Environmental performances of different manufacturing approaches	Life-Cycle Assessment and other methodology

UNILJ – Slovenia

Proposal 1 Cloud Robotic

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Compare various types of communication protocols between robots and a cloud in the context of M2M interaction and select a suitable solution for a given case study scenario.	Compare Select	Communication protocols, suitable solutions	M2M interaction

Proposal 2 UN SDG

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Describe the activities relevant to reaching UN SDGs from the perspective of mechanical engineering.	Describe	Activities relevant to reach UN SDG goal	Mechanical engineering

LBORO – United Kingdom

Proposal 1 Autonomous Robot

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	The student shall be able to describe perception methods and deliberation techniques of robotic autonomy and select the suitable method/technique for different application environments.	Describe Select	Perception methods and deliberation techniques	Robotic autonomy, application environments.
ILO 2	The student shall be able to program and develop a successful control logic of an autonomous robot.	Program Develop	Control logic	Autonomous robot

UNIPI- Italy

For Pisa University there were some changes from what was proposed in O2 and what was developed in O3 due to changed conditions during the project.

Proposal 1 AM in medical implants

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	The student should be able to compare and select among classical polymers, metals, and ceramics as well as innovative biodegradable materials in the context of additive manufactured medical prosthesis by minimizing the environmental impact	Compare Select	Different materials for additively manufactured medical prothesis	Minimal environmental impact
ILO 2	The student should be able to design and optimize the environmental impact of AM processes for single medical devices production	Design Optimize	AM process Environmental impact	Single medical devices production

Proposal 2 Digital learning

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	The student should be able to evaluate the economic and environmental impact of new digital technologies in the current operations of a real Manufacturer case study.	Evaluate	Economic and environmental impact of new digital technology	Operations of a real Manufacturer case study

Proposal 3 Cobots

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	The student should be able to design a shared space between man and robot, considering ergonomic and safety issues focusing on the automation of repetitive or dangerous manufacturing processes.	Design Considering	Shared space between man and robot, ergonomic and safety issue	Automation of manufacturing processes

Funded by the European Union

UNINOVA

Proposal 1 Cognition and autonomous systems

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1	Describe and discuss the trade-off between robot performance and energy efficiency when applied in production environment	Describe Discuss	The trade-off between robot performance and energy efficiency	Production environment
ILO 2	Programme a robot line to use energy saving algorithms based on real time information they collect from the MES in a provided simulated production environment.	Programme Collect	A robot line to use energy saving algorithms On real time information collected	MES in a provided simulated production environment.

Suggested Teaching and Learning Activities

The template for the formulation of the TLA is emphasizing the following dimensions:

- What is the teacher supposed to do to enact the underlying ILO
- What is the learner supposed to do to enact the underlying ILO
- How does the suggested activity relate to good teaching practices as expressed in the 7 principles of good learning[2]

KTH –Sweden

Proposal 1 AR and VR for Assembly

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 Explain and use suitable AR and VR implementations for assembly on a lean shop floor.	**TA 1.1:** Present AR and VR technology in a lean assembly context. **TA 1.2:** Explain how AR and VR technology can be applied for assembly instructions. **TA 1.3:** Create and show a real application of AR and VR for assembly instructions in the assembly line used for the lab session. **TA 1.4:** Encourage discussion on the application provided.	**LA 1.1:** Listen to the presentation, take notes and ask questions. **LA 1.2:** Listen to the presentation, take notes and ask questions. **LA 1.3:** Review the notes to recall the key points of AR and VR applications. Observe the AR and VR demonstration and apply it on the application provided. **LA 1.4:** Discuss about the experience on the application provided.	Encourages contact between students and faculty: LA 1.1 LA1.2 Develops reciprocity and cooperation among students Not applicable Encourages active learning: TA 1.3 TA 1.4 LA 1.3 LA 1.4 Gives prompt feedback: TA 1.4 LA 1.3 LA 1.4 Emphasizes time on task Not applicable Communicates high expectations Not applicable

[2] 7 principles of good learning:
- encourages contact between students and faculty,
- develops reciprocity and cooperation among students,
- encourages active learning,
- gives prompt feedback,
- emphasizes time on task,
- communicates high expectations
- respects diverse talents and ways of learning

Arthur W. Chickering and Zelda F. Gamson (1987)

			Respects diverse talents and ways of learning: TA 1.3 LA 1.3

PRZ- Poland

Proposal 1 Decision Support Systems

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 The student shall be able to apply time series analysis techniques to examine the relationship between time series and to search for patterns relevant to support decision-making in the analysed area and interpret the achieved results.	**TA 1.1:** Explain the concept of time series, its structure, and purposes of time series analysis. Answer any students' questions. **TA 1.2:** Ask students to indicate examples of time series that can be found in business or engineering. Add the unmentioned examples of time series. **TA 1.3:** Describe techniques (especially machine learning techniques) used to examine the relationship between time series and to search for patterns in time series. Answer any students' questions. **TA 1.4:** Ask students what kind of machine learning methods and techniques they know from university or from self-learning. Encourage discussion on the application of the above-mentioned methods and techniques. **TA 1.5:** Provide data sets that contain exemplary time series regarding, for example, values of manufacturing process parameters, media	**LA 1.1:** Listen to the explanation, take notes, and ask questions. **LA 1.2:** Indicate examples of time series. Determine the purposes of the analysis for the mentioned time series. **LA 1.3:** Listen to the explanation, take notes, and ask questions. **LA 1.4:** Indicate known machine learning methods and techniques and discuss about their potential applications. **LA 1.5:** Listen to the explanation, take notes, and ask questions.	Encourages contact between students and faculty: LA1.2 LA1.4 LA1.6 LA1.7 LA1.8 LA1.9 Develops reciprocity and cooperation among students: LA1.4 LA1.6 LA1.9 Encourages active learning: LA1.2 LA1.4 LA1.6 LA1.7 LA1.8 LA1.9 Gives prompt feedback: LA1.2 LA1.4 LA1.6 LA1.9 Emphasizes time on task: LA1.9 Communicates high expectations: LA1.7 LA1.8 LA1.9 Respects diverse talents and ways of learning:

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	consumption or patient monitoring. Describe the datasets and their origin. Answer any students' questions. **TA 1.6:** Ask students to indicate what kind of analysis can be apply on the provided data sets. Clarify the indicated analysis and add the unmentioned time series analysis techniques. **TA 1.7:** Prepare the data for analysis (data preprocessing) using an appropriate software. Explain the obtained results. Answer any students' questions. **TA 1.8:** Use the software for time series analysis (especially classification and regression) on delivered data sets in the context of decision-making support. Answer any students' questions. **TA 1.9:** Encourage students to indicate insights for 3 minutes. Formulate conclusions. Encourage discussion on the obtained results. Make a summary of performed tasks.	 **LA 1.6:** Indicate of possible applications of time series analysis techniques on the provided data sets. **LA 1.7:** Perform tasks related to data preprocessing, observe the results, take notes, and ask questions. **LA 1.8:** Perform tasks related to classification and regression in time series, observe the results, take notes, and ask questions. **LA 1.9:** Indicate insights and conclusions based on obtained results, discuss about conclusions. Take notes about performed tasks and their results.	LA1.1 LA1.3 LA1.5 LA1.7 LA1.8 LA1.9

Proposal 2 Lean Manufacturing

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 Develop a value stream map taking into account economic, social and environmental aspects.	**TA 1.1:** Present Sustainable Value Stream Mapping (Sus-VSM) methodology. Answer any students'	**LA 1.1:** Listen to the explanation, take notes, and ask questions.	Encourages contact between students and faculty: LA 1.1 LA 2.1
	questions.	**LA 1.2:**	LA 3.1

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
		Develop of current state of Sustainable Value Stream Map based on a set of data delivered by a teacher	Develops reciprocity and cooperation among students: LA 3.6 Encourages active learning: LA 1.1 LA 1.2 LA 2.1 LA 2.2 LA 3.2 LA 3.4 Gives prompt feedback: TA 1.1 TA 2.1 TA 3.1 TA 3.2 Emphasizes time on task: LA 1.2 LA 2.2 LA 3.2 LA 3.4 Comunicate high expectations: TA 1.1 TA 2.1 TA 3.1 TA 3.2 Respects diverse talents and ways of learning: LA 1.2 LA 2.2 LA 3.3 LA 3.5
ILO 2 Analyse a current state value stream map taking into account economic, social and environmental aspects.	**TA 2.1:** Present a methodology of Sustainable Value Stream Map Analysis. Answer any students' questions.	**LA 2.1:** Listen to the explanation, take notes, and ask questions. **LA 2.2:** Analyse of Sustainable Value Stream Map.	
ILO 3 Create a future state of the value stream map taking into account IoT solutions.	**TA 3.1:** Present a methodology of future state of Sustainable Value Stream Map development. Answer any students' questions. **TA 3.2:** Present IoT solutions possible to be implemented in manufacturing area. Answer any students' questions.	**LA 3.1:** Listen to the explanation, take notes, and ask questions. **LA 3.2:** Develop of future state of Sustainable Value Stream Map **LA 3.3:** Explain the improvements to be achieved by implementation of future state of Sustainable Value Stream Map **LA 3.4:** Develop proposals of IoT implementation **LA 3.5:** Explain the improvements to be achieved by implementation of the proposed IoT solutions **LA 3.6:** Ask questions about solutions proposed by other students.	

Proposal 3 Risk Management

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1	**TA 1.1:**	**LA 1.1:**	

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
Develop model of disease spread using System Dynamics method.	Present System Dynamics modeling principles and sample models. Answer any students' questions. **TA 1.2:** Formulate and discuss the assumptions of the epidemic spread model	Listen to the explanation, take notes, and ask questions. **LA 1.2:** Discuss assumptions and develop model of disease spread	Encourages contact between students and faculty: TA1.1 TA1.2 LA1.1 LA1.2 TA2.1 LA2.1 Develops reciprocity and cooperation among students: Not applicable Encourages active learning: LA 1.1 LA 1.2 LA 2.1 TA 2.1 Gives prompt feedback: TA 1.1 TA 1.2 TA 2.1 Emphasizes time on task: LA 1.2 LA 2.1 Communicates high expectations: TA 1.1 TA 2.1 Respects diverse talents and ways of learning: LA 1.2 LA 2.1
ILO 2 Analyses the simulation results concerning impact of ICT solutions on disease spread and project risk.	**TA 2.1:** Provide a scenario of disease spread and parameter values / ranges. Discuss the results.	**LA 2.1:** Assess the impact of ICT solutions on disease spread and project risk and discusses the results	

POLITO – Italy

Proposal 1 Life-Cycle Assessment

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 Compare the environmental performance of different manufacturing	**TA 1.1:** Describe the different manufacturing processes with reference to their environmental impact.	**LA 1.1:** Listen to the explanation, take notes, and ask questions.	Encourages contact between students and faculty: LA 1.1 LA 1.2

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
approaches by modelling their sustainability through Life-Cycle Assessment and other state-of-the-art methodologies.	**TA 1.2:** Explain the procedure for executing Life-Cycle Assessment (LCA). **TA 1.3:** Explain the pro and cons of other methodologies alternative to LCA **TA 1.4:** Assign individual classwork to apply LCA to a manufacturing process with given input data. **TA 1.5:** Create working groups of students and assign the task of assessing different manufacturing technologies from the viewpoint of environmental impact. Give them deadlines and waypoints. Support and instruct the data collection on the problem, executed by students. **TA 1.6:** Organize a final wrap up opportunity where each group will present and defend the outcomes of its work.	**LA 1.2:** Listen to the explanation, take notes, and ask questions. **LA 1.3:** Listen to the explanation, take notes, and ask questions. **LA 1.4:** Review the notes, find similar solutions applicable to the given problem, produce the LCA **LA 1.5:** Distribute tasks among the group Write a checklist of activities and a GANTT and monitor the progress of the work. Discuss in groups and solve the case study. Prepare the presentation to the whole class. **LA 1.6:** Present the work and answer to the questions of the class.	LA 1.3 Develops reciprocity and cooperation among students: LA 1.5 LA 1.6 Encourages active learning: LA 1.4 LA 1.5 Gives prompt feedback: LA 1.4 LA 1.5 LA 1.6 Emphasizes time on task: LA 1.5 Communicates high expectations: LA 1.5 LA 1.6 Respects diverse talents and ways of learning LA 1.5 LA 1.6

UNILJ – Slovenia

Proposal 1 Cloud Robotic

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO1 Compare various types of communication protocols between robots and a cloud in the context of M2M interaction and select a suitable solution	**TA 1.1:** Provide recommended basic reading on communication protocols between robots and a cloud. **TA 1.2:**	**LA 1.1:** Read the given text and annotate it by writing margin notes (i.e. write down questions, mark the key parts of the text).	Encourages contact between students and faculty: LA 1.4 LA 1.5. Develops reciprocity and cooperation among students:

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
for a given case study scenario.	Create a concept map based on the inputs of the students. Collect students' questions they wrote down during reading. **TA 1.3:** Present the most relevant communication protocols between robots and a cloud in the context of M2M interactions together with its advantages and disadvantages using slides. Address the gathered questions and encourage students to ask new questions. **TA 1.4:** Randomly place students in groups of XX and ask each group to select one case study scenario. Each group has to select suitable communication protocols in 15 minutes and prepare itself for justifying its selection. **TA 1.5:** Ask each group to nominate one student to present their case and the solution in 3 minutes. Encourage students of other groups to discuss the presented solution in 5 minutes. Present the ideal solution for the given case study scenario after discussion is finished. **TA 1.6:**	**LA 1.2:** Provide inputs to a concept map and your questions that emerged during the reading. **LA 1.3:** Listen to the presentation, take notes, and ask questions. **LA 1.4:** Discuss the given case study scenario in groups and select a suitable solution. Prepare yourself to discuss it with the whole class. **LA 1.5:** Explain your selection and take part in the discussion. Listen and take notes on the ideal solution. **LA 1.6:**	LA 1.4 LA 1.5 Encourages active learning: LAs 1.2 LA 1.4 LA 1.5 LA 1.6 Gives prompt feedback: LA 1.4 LA 1.5 LA 1.6 Emphasizes time on task: LA 1.4 LA 1.5 Communicates high expectations: LA 1.4 LA 1.5 Respects diverse talents and ways of learning LA 1.1 LA1.2 LA 1.3 LA 1.6

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	Encourage students to ask questions (those from the reading session that were potentially not answered as well as the ones that emerged during the lecture).	Ask any unanswered questions and take notes if needed.	

Proposal 2 UN SDG

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 Describe the activities relevant to reaching UN SDGs from the perspective of mechanical engineering.	**TA 1.1:** Give an overview of the UN SDGs. **TA 1.2:** Ask the students to identify the SDGS that are the most relevant from the perspective of mechanical engineering. Encourage discussion and comment on students' answers. **TA 1.3:** Present the most relevant UN SDGs from the perspective of mechanical engineering. **TA 1.4:** Ask the students to do a one minute paper on the activities relevant to reaching UN SDGs from the perspective of mechanical engineering. **TA 1.5:** Address the one minute papers at the beginning of the next lecture.	**LA 1.1:** Listen to the lecture, take notes and ask questions. **LA 1.2:** List UN SDGs that you find most relevant from the perspective of mechanical engineering. Take part in the discussion. **LA 1.3:** Listen to the lecture, take notes and ask questions. **LA 1.4:** Do the one minute paper writing activity. **LA 1.5:** Listen to the lecturers' remarks, take notes and ask questions.	Encourages contact between students and faculty: LA 1.2 Develops reciprocity and cooperation among students: Not applicable Encourages active learning: LA 1.2 LA 1.4 Gives prompt feedback: LA 1.2 Emphasizes time on task: LA 1.2 LA 1.4 Communicates high expectations: LA 1.2 Respects diverse talents and ways of learning: LAs 1.1 LA 1.3 LA 1.4 LA 1.5

LBORO – United Kingdom

Proposal 1 Autonomous Robot

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 The student shall be able to describe perception methods and deliberation techniques of robotic autonomy and select the suitable method/technique for different application environments.	**TA 1.1:** Explain the concept and motivations for perception methods using slides. Answer any students' questions. **TA 1.2:** Ask students to name different type of perception methods and possible application environments based on their potential and limitations. Clarify the named methods one by one and add the unmentioned methods. **TA 1.3:** Explain the concept of deliberation. Answer any students' questions. **TA 1.4:** Ask students why they think deliberation is important for robot autonomy. Comment on their answers and encourage discussion. **TA 1.5:** Ask students to name different deliberation technique and possible applications. Clarify the named methods one by one and summarize the complete technique. **TA 1.6:** Provide number of diverse application cases and ask students in group of four to select one case. Each group must select suitable	**LA 1.1:** Listen to the explanation, take notes, and ask questions. **LA 1.2:** Name different perception methods and discuss their potential and limitations and applications environments. **LA 1.3:** Listen to the explanation, take notes, and ask questions. **LA 1.4:** Answer the query and discuss their views. **LA 1.5:** Name and discussing different deliberation techniques and application environments. **LA 1.6:** Discuss in groups and solve the case study. Prepare to discuss it with the whole class.	Encourages contact between students and faculty: LA 1.2 LA 1.4 LA 1.5 LA 1.6 LA 1.7 Develops reciprocity and cooperation among students: LA 1.4 LA 1.6 LA 1.7 Encourages active learning: LA 1.2 LA 1.4 LA 1.5 LA 1.6 LA 1.7 Gives prompt feedback: LA 1.2 LA 1.4 LA 1.5 LA 1.7 Emphasizes time on task: LA 1.7 Communicates high expectations: LA 1.4 LA 1.5 LA 1.6 Respects diverse talents and ways of learning: LA 1.1 LA 1.3 LA 1.6

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	perception methods and deliberation technique in 10 minutes and justify their selections to discuss it with whole class. **TA 1.7:** Ask each group to nominate one student to explain the case and the solution in 3 minutes. Encourage students to ask questions for 5 minutes. Explain the ideal solution of each case.	**LA 1.7:** Explain their solution and answer questions. Take note about the ideal solution.	
ILO 2 The student shall be able to program and develop a successful control logic of an autonomous robot.	**TA 2.1:** Ask the students to write in one minute paper about what are the differences in control logic of autonomous robot compared to other automation logics (i.e., CNC machine tool, conveyors). **TA 2.2:** Explain the specific aspect of control logic for autonomous robot. Answer any students' questions. **TA 2.3:** Ask the students to answer the previous question again in two minutes and compare their answers. **TA 2.4:** Set a course work of developing a control logic using a suitable drag and play robot platform. Apply the logic to an educational robot in a lab environment. Ask the student to do it in group of two step by step in a specified timing and provide ongoing feedback.	**LA 2.1:** Write in one minute paper the differences in autonomous robots. **LA 2.2:** Listen to the explanation, take notes, and ask questions. **LA 2.3:** Answer the question again and compare the two answers. **LA 2.4:** Watch the demonstration and apply it in an ongoing step by step. Seek help for unclear step.	Encourages contact between students and faculty: LA 2.1. LA 2.2 LA 2.3 LA 2.4 Develops reciprocity and cooperation among students: LA 2.1 Encourages active learning: LA 2.1 LA 2.3 LA 2.4. Gives prompt feedback: LA 2.2 LA 2.4 Emphasizes time on task: LA 2.1 LA 2.3 LA 2.4 Communicates high expectations: Not applicable Respects diverse talents and ways of learning: LA 2.4

UNIPI- Italy

For Pisa University there were some changes from what was proposed in O2 and what was developed in O3 due to changed conditions during the project

Proposal 1 AM in medical implants

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO1 The student should be able to compare and select among classical polymers, metals and ceramics as well as innovative biodegradable materials in the context of additive manufactured medical prosthesis by minimizing the environmental impact	**TA 1.1:** Explain the main theoretical topics concerning AM classical and innovative materials, environmental impact of the production processes, basics and fundamentals of additive manufacturing, experimental energy analysis for rapid prototyping approaches (Lectures). **TA 1.2:** Provide examples of AM processes parameters and material selection in medical sectors by using Criteria generation, multicriteria selection..etc (Tutorial) Generate feedback for the one minute paper. **TA 1.3:** Assign a case study as a classwork and generate feedback.	**LA 1.1:** Listen, query, discuss with peers and produce an infographic to explain, describe, and visualise the information at the end of each lecture. **LA 1.2:** Interact with peers and teachers during the Tutorial. Discuss the dimostration and summarize the main concepts in one minute paper. **LA 1.3:** Apply the concepts in the given case study. Create a 10 minute oral explanation of it. The oral explanation is then shared with the other members of the class, either as a recording shared online, or through a live presentation during a scheduled session.	Encourages contact between students and faculty: LA1.3 Develops reciprocity and cooperation among students: LA1.1 LA1.2 LA1.3 Encourages active learning: not applicable Gives prompt feedback: LA1.3 Emphasizes time on task: LA1.3 Communicates high expectations: LA1.3 Respects diverse talents and ways of learning: LA1.3
ILO 2 The student should be able to design and optimize the environmental impact of AM processes for single medical devices production	**TA 2.1:** Present and Explain energy analysis for rapid prototyping approaches, design methodology, pros/cons, environmental impact frameworks and standards.	**LA 2.1:** Listen, query, discuss with peers and produce an infographic to explain, describe, and visualise the information at the end of each lecture.	Encourages contact between students and faculty: not applicable Develops reciprocity and cooperation among students: LA2.1

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	TA 2.2: Provide updated case studies through seminars on medicine and AM prosthesis by a sustainable perspective. **TA 2.3**: Set brief and provide ongoing feedback on Project work. Organise students into groups of three or four and provided with a real case study project. **TA 2.4**: Provide prompt feedback to each group during the project development.	**LA 2.2:** Listen, query, discuss with peers and seminar guests experts as well **LA 2.3:** Discussion inside the group and provide/share ideas by a 30 minute final presentation. Check understandings with one another to then take back to the group and improve the project in a second round based on peers and teacher review. **LA 2.4:** Provide 1 hour final presentation to the whole class.	LA2.2 LA2.3 Encourages active learning: LA2.2 Gives prompt feedback: LA2.3 Emphasizes time on task: LA2.3 LA2.4 Communicates high expectations: LA2.4 Respects diverse talents and ways of learning: LA2.3 LA2.4

Proposal 2 Digital learning

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO1 The student should be able to evaluate the economical and environmental impact of new digital technologies in the current operations of a real Manufacturer case study.	**TA 1.1:** Explain the main theoretical topics about business process mapping, lean tools and practices, i4.0 enabling technologies and sustainability (Lecture) **TA 1.2:** Ask students to produce an infographic that connects the previous mentioned topic and propose real examples (Lecture). **TA 1.3:**	**LA 1.1:** Listen, query, discuss with peers **LA 1.2:** Produce an infographic (e.g., mind map) to explain, describe, and visualise the information at the end of each lecture.	Encourages contact between students and faculty: not applicable Develops reciprocity and cooperation among students: LA1.1 LA1.3 Encourages active learning: LA1.1 LA1.2 LA1.3 Gives prompt feedback: LA1.5

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	Invite real company to explain the specific case study (seminar). **TA 1.4:** Assign a group of students to each real case study presented by the companies' references (Group works). **TA 1.5:** Provide ongoing feedback on a real case study project (Group works) **TA 1.6:** Analyze and review the final reports in order to present them to the reference company.	**LA 1.3:** Listen, query, discuss with peers and the company references as well **LA 1.4:** Analyse the given case study and apply at least one i4.0 technology in a lean and sustainable way. **LA 1.5:** Explain the "as is" situation along with economical and environmental , impact of proposed new digital technologies implementation by providing a final report **LA 1.6:** Present the final report to the company reference in a 30 minute speech. Answer questions and provide explanations on the main assumptions.	Emphasizes time on task: LA1.6 Communicates high expectations: LA1.5 LA1.6 Respects diverse talents and ways of learning: LA1.6

Proposal 3 Cobots

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO1 The student should be able to design a shared space between man and robot, considering ergonomic and safety issues focusing on the automation of repetitive or dangerous manufacturing processes.	**TA 1.1:** Explain and detail the main theoretical topics such as principles of automation, work cell, collaborative robot, characteristics and differences with respect to traditional robots, safety and ergonomic issues and standards (Lecture) **TA 1.2:**	**LA 1.1:** Listen, query, discuss with peers and produce an infographic to explain, describe, and visualise the information at the end of each lecture. **LA 1.2:** Students are provided with a scenario, and they	Encourages contact between students and faculty: not applicable Develops reciprocity and cooperation among students: LA1.1 LA1.2

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
	Provide examples and real applications of industrial automation of real cases and examples of collaborative applications (seminar) **TA 1.3**: Provide simulation by practical exercise on software and code generation (tutorial). **TA 1.4**: Set brief and provide ongoing feedback on Project work. Students are organised into groups of three or four and provided with a real case study project.	then interact with peers, teacher and expert guest in an interactive seminar. **LA 1.3:** Programming of collaborative robots both by manual programming and dedicated software. **LA 1.4**: Analyse operations and subdivision into logical levels (skills, tasks, primitives). Implement safety functions within the program and division of collaborative zones. Set parameters and operating limits. Setting of safety inputs; interface with the end-effector and all other devices / machines inside the work area. Define an ergonomic operator-cobot interface	Encourages active learning: LA1.1 LA1.2 LA1.3 LA1.4 Gives prompt feedback: LA1.2 Emphasizes time on task: LA1.3 Communicates high expectations: not applicable Respects diverse talents and ways of learning: LA1.2

UNINOVA

Proposal 1 Cognition and autonomous systems

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning
ILO 1 Describe and discuss the trade-off between robot performance and energy efficiency when applied in production environment	**TA 1.1:** Lecture about the energy use and consumption under different operative conditions **TA 1.2:** Prepare self-assessing quizzes	**LA 1.1:** Take notes and follow the class **LA1.2:** Complete their understanding through self- assessing quizzes	Encourages contact between students and faculty: LA 1.1 Develops reciprocity and cooperation among students: LA 1.3 Encourages active learning:

	TA 1.3: Moderate a discussion forum about the open topics in the discipline	**LA 1.3:** Discuss the question proposed by the teacher and the answer from the peers	LA 1.2, LA 1.3 Gives prompt feedback: LA 1.3 Emphasizes time on task: LA 1.2 Communicates high expectations: LA 1.3 Respects diverse talents and ways of learning: LA 1.2
ILO 2 Programme a robot line to use energy saving algorithms based on real time information they collect from the MES in a provided simulated production environment.	**TA 2.1:** Tutorial on the implementation of an energy saving algorithm connected in real time to the production daily schedule in a simulated environment **T2.2:** Meet students and answer to question regarding the project	**LA 2.1:** Project where the student program similar algorithms on a self-designed production workflow. The project is carried out using the simulated production environment presented by the teacher.	The activity LA 2.1 is designed to address all the 7 principles

Suggested Assessment Task

The template for the formulation of the AT is emphasizing different assessment strategies for different verbs and different learning style.

KTH –Sweden

Proposal 1 AR and VR for Assembly

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO 1 Explain and use suitable VR and AR implementations for assembly on a lean shop floor.	Verb: Explain Activity type: Exam essay question Answer questions regarding the presented AR and VR applications discussing on the experience had during the lab session. Grading: assessment by grades (A, B, C, D, E, F)	Verb: Use Activity type: Laboratory session. Use the AR and VR application developed for assembly instructions Grading: assessment by P/F

PRZ- Poland

Proposal 1 Decision Support Systems

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2	Assessment task 3	Assessment task 4	Assessment task 5
ILO 1 Apply time series analysis techniques to examine the relationship between time series and to search for patterns relevant to support decision-making in the analysed area and interpret the achieved results.	Verb: Apply Activity type: Case study. Based on sample data (time series from e.g. industry, healthcare, media consumption), develop a model for classification or regression tasks that gives an insight into relationship between time series. Grading: assessment by P/F	Verb: examine Activity type: Case study. For the developed model, create a chart that shows importance of input variables in the model. Grading: assessment by P/F	Verb: search Activity type: Case study. Based on sample data, perform a time series clustering that reveals groups of similar time series. Grading: assessment by P/F	Verb: support Activity type: Case study. Use of the created model to predict the value of the output variable based on the values of the input variables. Grading: assessment by P/F	Verb: interpret Activity type: Test. Answer questions about the techniques of machine learning and generated results. Grading: assessment by grades

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Proposal 2 Lean Manufacturing

ILO reference (Highlight the Verb)	Assessment task 1
ILO 1 Develop a value stream map taking into account economic, social and environmental aspects.	Verb: Develop Activity type: Project. Based on sample data (manufacturing processes sequence, processing time, type of processes, material utilization, energy utilization, machines, tools and equipment used in the process, number of employees, wastes, work In process etc.) student creates a value stream map – a current state. Grading: assessment by grades
ILO 2 Analyse a current state value stream map taking into account economic, social and environmental aspects.	Verb: Analyse Activity type: Case study. Following the procedure, a student analyze the current state of a value stream map and identify wastes and possibilities for improvements Grading: assessment by grades

Proposal 3 Risk Management

ILO reference (Highlight the Verb)	Assessment task 1
ILO 1 Develop model of disease spread using System Dynamics method.	Verb: Develop Activity type: Project Based on sample data (population, initial infected, infection rate, recovery rate), develop a causal diagram and a model of epidemic spread identify feedback loops. Grading: assessment by grades
ILO 2 Analyses the simulation results concerning impact of ICT solutions on disease spread and project risk.	Verb: Analyses Activity type: Case study Compare the infection spread simulation results for different infection rates, recovery rates, population and initial infected. Grading: assessment by grades

POLITO – Italy

Proposal 1 Life-Cycle Assessment

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO 1 Compare the environmental performance of different manufacturing approaches by modelling their sustainability through Life-Cycle Assessment and other state-of-the-art methodologies.	Verb: Compare/Model Activity type: Case study The content of the case study addresses environmental performance of manufacturing approaches in the context of Life cycle of products Grading: n.a.	Verb: Evaluate Activity type: Online exam Grading: The assessment of the whole course is expressed in thirtieths and the exam is passed if the mark is at least 18/30. A subset of the written exam (5 or 10%, i.e., 2 or 4/30 points) is dedicated to this ILO.

UNILJ – Slovenia

Proposal 1 Cloud Robotic

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO1 Compare various types of communication protocols between robots and a cloud in the context of M2M interaction and select a suitable solution for a given case study scenario.	Verb: Compare and select Activity type: Case study For a given cloud robotics case create a chart that shows two most appropriate robot to cloud communication protocols together with their advantages and disadvantages. Grading: assessment by grades	Verb: Compare Activity type: Multiple choice questions Answer questions about the communication protocols between robot and a cloud together with their advantages and disadvantages. Grading: assessment by grades

Proposal 2 UN SDG

ILO reference (Highlight the Verb)	Assessment task 1
ILO 1 Describe the activities relevant to reaching UN SDGs from the perspective of mechanical engineering.	Verb: Describe Activity type: Essay question exam For a given mechanical engineering application define which UN SDGs could this application impact (directly and indirectly). Impact can be both negative and positive. Grading: assessment by grades

LBORO – United Kingdom

Proposal 1 Autonomous Robot

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO 1 The student shall be able to describe perception methods and deliberation techniques of robotic autonomy and select the suitable method/technique for different application environments.	Verb: describe Activity type: Test Fill in the gaps of the given questions about perception methods and deliberation techniques. Answer question about describing perception methods and deliberation techniques. Grading: assessment by grades (range 0% - 100%)	Verb: select Activity type: Case study For the given case study, select suitable perception method(s) and deliberation technique(s) and justify their selections. Grading: assessment by grades (range 0% - 100%)
ILO 2 The student shall be able to program and develop a successful control logic of an autonomous robot.	Verb: program Activity type: Project For a given task environment, use the provided code skeleton to program a control logic for an autonomous robot to perform the task. Grading: assessment by grades (range 0% - 100%, Marking rubric provided to students)	Verb: develop Activity type: Project Apply the developed control logic in the simulation platform used in the course work. Grading: assessment by grades (range 0% - 100%, Marking rubric provided to students)

UNIPI- Italy

For Pisa University there were some changes from what was proposed in O2 and what was developed in O3 due to changed conditions during the project

Proposal 1 AM in medical implants

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO1 The student should be able to compare and select among classical polymers, metals and ceramics as well as innovative biodegradable materials in the context of additive manufactured medical prosthesis by minimizing the environmental impact	Verb: select Activity type: Written report Demonstrate capability in the use of methodology and tools for the selection process retrived in the literature review for the project. The selected material and process must be clearly demonstrated. Grading: assessing by scores [18,30]	Verb: compare Activity type: Oral exam Answer to theoretical question both on AM innovative technologies and material comparison. Explain Main differences on sustainability pros and cons using comparison methods Grading: assessing by scores [18,30]
ILO2	Verb: design	Verb: optimize

The student should be able to design and optimize the environmental impact of AM processes for single medical devices production	Activity type: Written report Present a final written report of the project to the professor. The group is assessed on the main standard attributes of the project: Problem presentation and literature review, CAD design, AM software and implemented solution, material selcetion, practical prototype realization and Sustainability assessment. Grading: assessing by scores [18,30]	Activity type: Written report Explain Actual AM Energy consumption must be accounted by apprpriate physical model and desing possible improvement Grading: assessing by scores [18,30]

Proposal 2 Digital learning

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2
ILO1 The student should be able to evaluate the economical and environmental impact of new digital technologies in the current operations of a real Manufacturer case study.	Verb: evaluate Activity type: Project final oral presentation to the professor Evaluate the best suited i4.0 tech. and the feasibility together with the sustainability impact. Cost and saving must be highlighted and objectivated both from economical and environmental framework. Detailed description for the evaluation method in the selection of new digital tech must be presented. Grading: assessing by scores [18,30]	Verb: evaluate Activity type: Project final oral presentation to the company Provide short written report along with a ppt presentation for the company presentation (if the Assessment task 1 is passed with more than 28/30) Grading: assessing by scores [28,30]

Proposal 3 Cobots

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 3
ILO1 The student should be able to design a shared space between man and robot, considering ergonomic and safety issues focusing on the automation of	Verb: design Activity type: Final written report Design and provide a final report contining: Problem presentation, risk and ergonomic analysis, solutions (HW+SW) presentation, solutions (HW+SW) selection,	Verb: design Activity type: Oral exam Program code (both manual programming and commercial software syntax)

repetitive or dangerous manufacturing processes.	possible solution (HW+SW) implementation and relation to SDGs	

UNINOVA

Proposal 1 Cognition and autonomous systems

ILO reference (Highlight the Verb)	Assessment task 1
ILO 1 Describe and discuss the tradeoff between robot performance and energy efficiency when applied in production environment	Verb: describe Activity type: Open question during the final exam Grading criteria: assessment by grades
ILO 2 Programme a robot line to use energy saving algorithms based on real time information they collect from the MES in a provided simulated production environment.	Verb: programme Activity type: final project report Grading criteria: from the related TLA it will be evaluated for correctness and concur to the final grade

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Summary of the proposed educational units and plan for the implementation

The plan for the implementation of the prosed educational units is reported in the following table. As previously anticipated, MAESTRO will implement 5 educational units.

Institution	Proposal	Implementation	When	N students
KTH	AR and VR for Assembly	**Yes**	Autumn 2021	120
PRZ	Decision Support Systems	**Yes**	Spring 2022	30
	Lean Manufacturing	**Yes**	Autumn 2021	30
	Risk Management	**No**		
POLITO	Life-Cycle Assessment	**Yes**	Spring 2021	150
UNILJ	Cloud Robotic	**No**		
	UN SDG	**No**		
LBORO	Autonomous Robot	**No**		
	Future Automation Strategy	**No**		
UNIPI	AM in medical implants	**Yes**	Spring 2022	30
	Digital lean	**No**		
	Cobots	**No**		

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Appendix 1 Input from O2

This appendix introduces the Candidate Educational Units from each partner that were used as basis for the development in O3.

Some Acronyms:

- ILO- Intended Learning Outcome
- TLA- Teaching and Learning Activities
- AT- Assessment task

KTH –Sweden

Proposal 1 AR and VR for Assembly

Responsible: Eleonora Boffa

Assigned for the development: Eleonora Boffa, Andrea De Giorgio, Hakan Akillioglu

Reference Program	*Management Engineering*
Reference course/s	*Production engineering Planning and control*
Current ILO* /content	Utilize appropriate lean tools to continuously improve shop floor performance Laboratory sessions content: Concepts and tools of the lean philosophy given in lectures will be analyzed and implemented on a real assembly system operated by students.
Description of proposed modification /addition	Extending the current ILO to include the use of Augmented Reality (AR) technology, in terms of human interaction and training. The extended ILO assumes acquiring the skills to use AR technology. Laboratory sessions content: Students will be able to have hands on experience on lean applications on a real assembly line. AR will be employed to give assembly instructions to the students. The technology will contribute to decrease the possibility of misinterpretation of written instructions. Consequently, this leads to reduce production scraps and to increase time efficiency at each work station.
New content	**Reference Technology/ies:** **E5**: Augmented Reality - Training (How to support assembly operations using AR applications?) **E5:** Augmented Reality – Communication (How to improve communication and perception of the assembly enviroment using AR applications?)

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	Reference Sustainability goal/s: **SDG 3** - Good Health and Well-being (How the work environment can be improved using AR applications?) **SDG 9** - Industry, Innovation and Infrastructure (How can the upgrade of technological capabilities strengthen the industry?)
Tentative new ILO	Apply appropriate lean tools to continuously improve shop floor performance. Use suitable AR implementations on a lean shop floor.
Tentative new TLA**	Lecture OR Seminar: - Presentation of AR applications in manufacturing area Lab session: - Discussion and suggest possible AR implementations in the assembly line used for the exercise.
Tentative AT***	Practical use of AR in the lab.
Other	

Proposal 2 FEM and lab analysis in CAD

Responsible: Nathaly Rea

Assigned for the development: Nathaly Rea, Per Johansson

Reference Program	*Mechanical engineering / Production Engineering and Management*
Reference course/s	*CAD and other IT tools in industrial processes*
Current ILO* /content	ILO2 - Perform a simple analysis of the strength features of a part model, by using a FEM system ILO3 - Use a CAM system for creating a simple production plan for a part model, and build and use a machine tool model for simulation of the manufacturing process
Description of proposed modification /addition	As the ILOs are highly related to simulation, it can also address the use of data obtained from sensors to enrich the simulations and obtain results more in line with the current situation of the system or component to be studied or manufactured.

	It could be also helpful for explaining the impact of a change in the parameters used in these activities, such as machining processes and FEM analysis.
New content	**Reference Technology/ies:** **E1** – Internet of Things (IoT) – Ubiquitous sensing (What kind of sensing related devices exist in manufacturing tools and machine tools?) **E2 –** Big data & analytics – Sensors (Which sensors can be applied to retrieve the data according to the analyzed variable?) **E2 –** Big data & analytics – Data collecting (What kind of data can be collected? What amount of data would be necessary to obtain precise results?) **Reference Sustainability goal/s:** **SDG 9-**Industry, Innovation and Infrastructure (How the innovations in infrastructure can strengthen the industry?) **SDG 13**-Climate Action (How the data collected could be used to monitor energy usage machining processes towards making it more efficient?)
Tentative new ILO	ILO 2 – Develop a static structural analysis and simulation of a part model or system considering its working conditions using a FEM system. ILO 3 – Understand the use of CAM systems to generate production plans and simulations of the manufacturing processes integrating information about its current state aiming to its optimization.
Tentative new TLA**	• Seminar about types of sensors and variables to be measured, methods of direct and indirect quantification of variables of interest, sensors available in machine tools and special tools. • Analysis of a related case study.
Tentative AT***	A project developing a FEM analysis of a mechanical piece in a real situation. A project studying the variation in machining process due to change in its parameters.
Other	

PRZ- Poland

Proposal 1 Decision Support System

Responsible: Łukasz Paśko

Assigned for the development: Łukasz Paśko, Maksymilian Mądziel

Reference Program	*Industrial engineering*
Reference course/s	*Decision support systems*
Current ILO* /content	Recognize and model decision processes, identify structure and parameters of models, choose the right methods to solve or support a decision problem. **Lectures content:** Characteristics of decision-making processes; modelling decision-making processes, identifying the structure and parameters of models; phases of a decision-making process; characteristics of decisions at the operational, tactical and strategic levels; definition and genesis of decision support systems (DSS); DSS functions (recognizing a problem, classifying it into a specific decision group, creating models of data and processes, generating variants of possible solutions and helping to choose the best solution); a base of DSS models (analytical, single-criteria and multi-criteria models of mathematical programming, linear and non-linear, stochastic); preparing a database for the needs of DSS. **Laboratory classes content:** using software tools, such as Solver in MS Excel or MATLAB Optimization Toolbox, to support decision-making; using single-criterion optimization, linear and non-linear methods to support decisions in the following tasks: selection of the production assortment, assigning tasks to machines, scheduling working time, minimizing empty runs, optimizing flows in the transport network.
Description of proposed modification /addition	Extending the current ILO to include processing of large datasets and supporting decision-making based on information discovered in the data. The extended ILO assumes acquiring the ability to apply machine learning techniques to time series analysis. The ILO puts emphasis on technologies related to the enabler called "Big Data & analytics". In particular, the ILO covers the following elements of that enabler: data analytics, decision-making support. Depending on the analysed datasets, the ILO may refer to SDGs related to industry, healthcare, as well as sustainable cities and communities.
New content	**Reference Technology/ies:** **E2 -** Big Data & analytics - Data analytics (What kinds of machine learning methods can be applied to analysed datasets?) **E2 -** Big Data & analytics - Decision-making support (How to use patterns found in analysed datasets to support decision-making?) **Reference Sustainability goal/s:** **SDG 3** – Good Health and Well-being (How can medical data, e.g. from patients monitoring, be used to recognize patients' health?) **SDG 9** – Industry, Innovation and Infrastructure (How to use data on the values of the manufacturing process parameters to predict the number of defective products?) **SDG 11** – Sustainable Cities and Communities (How can media consumption data help forecast the use of water or electricity resources?)
Tentative new ILO	Apply time series analysis techniques to examine the relationship between time series and to search for patterns relevant to support decision-making in the analysed area and interpret the achieved results.
Tentative new TLA**	**Laboratory classes additional content:** Discussion on machine learning techniques used to analyse time series (1 hour). Using of an appropriate software for time series analysis: a case study based on delivered data set, on classification and regression in time series (2 hours).
Tentative AT***	A test on machine learning techniques used in laboratory classes.

	Practical tasks realized on computer workstations with the use of appropriate software, concerning the analysis of datasets.
Other	-

Proposal 2 Lean Manufacturing

Responsible: Dorota Stadnicka

Assigned for the development: Dorota Stadnicka, Maksymilian Mądziel

Reference Program	*Industrial engineering*
Reference course/s	*Lean Manufacturing*
Current ILO* /content	Develop a value stream map. Analyse the current state value stream map and based on the results propose a future state of the value stream map. **Lectures content:** Value stream mapping – rules for developing a current state map. Value stream mapping – analysis. Value stream mapping – rules used in the development of the future state map. **Project content:** Development of the current state of the value stream map. Value stream map analysis. Presentation of the proposed problem elimination and development of the state of the future value stream map.
Description of proposed modification /addition	**The proposed modifications** concern two aspects: 1. The extension of value stream mapping by including environmental aspects, i.e. implementation of Sustainable Value Stream Mapping. 2. The extension of value stream map improvement by including possible IoT solutions to collect data and perform current monitoring.
New content	**Reference Technology/ies:** **E1 -** Internet of Things (IoT) - Ubiquitous Sensing (What kind of sensing related devices exist in the manufacturing line?) **E2 -** Big Data & analytics – Sensors (What kind of sensors can be additionally applied?) **E2 -** Big Data & analytics – Data collecting (What kind of data can be collected?) **E2 -** Big Data & analytics – Data analytics (How the data can be used?) **Reference Sustainability goal/s:** **SDG 3** - Good Health and Well-being (How the work environment can be improved?) **SDG 6** - Clean Water and Sanitation (How the influence on water consumption and clean can be monitored?) **SDG 8** - Decent Work and Economic Growth (How the decent work and a company development can be achieved?) **SDG 9** - Industry, Innovation and Infrastructure (How the innovations in infrastructure can strengthen the industry?) **SDG 13** - Climate Action (How the influence on the climate can be monitored?)
Tentative new ILO	Develop a value stream map taking into account economic, social and environmental aspects.

	Analyse a current state value stream map taking into account economic, social and environmental aspects. Create a future state of the value stream map taking into account IoT solutions.
Tentative new TLA**	**Lectures changed content:** Presentation of Sustainable Value Stream Mapping (Sus-VSM) (2 hours). Analysis of Sustainable Value Stream Map (2 hours). Presentation of IoT possible implementation in manufacturing area (2 hours). Development of future state of Sustainable Value Stream Map (2 hours). **Project changed content:** Development of current state of Sustainable Value Stream Map (2 hours). Analysis of Sustainable Value Stream Map (2 hours). Proposals of IoT implementation (2 hours). Development of future state of Sustainable Value Stream Map (2 hours).
Tentative AT***	A test concerning Sus-VSM and IoT implementation. A project on Sustainable Value Stream Mapping.
Other	-

Proposal 3 Risk Management

Responsible: Paweł Litwin

Assigned for the development: Paweł Litwin, Maksymilian Mądziel

Reference Program	*Industrial engineering*
Reference course/s	*Risk management in IT projects*
Current ILO* /content	Know, understand and correctly apply the concepts related to risk management: risk, risk factors, impact of risk on the project, risk management methods. Identify sources of risk, model and conduct risk simulation, assess the impact of risk on the project, select remedial actions, assess the effects of the risk management system. **Lectures content:** Risk management methodologies. Risk areas in project activities, Identification of risk factors. Qualitative and quantitative assessment of risk. Modelling and simulation of risk using the System Dynamics method. Identification and selection of risk responses. Risk monitoring and control. **Laboratory classes content:** Identification of risk factors – case study. Qualitative and quantitative assessment of risk factors. Identification and selection of risk responses – case study. Risk management in an IT project – case study.
Description of proposed	Information and Communication Technologies (ICT) have been at the forefront of the fight against COVID-19. The epidemic has accelerated digitization of many areas of social activity, including teleworking and video conferencing systems in the workplace

modification /addition	and beyond, as well as access to health care, education and basic goods and services. In order to increase the use of ICT in the work of project teams, students should know how to assess the impact of these solutions on the spread of infections that pose a serious risk to the project.
New content	**Reference Technology/ies:** **E4** - Simulation **Reference Sustainability goal/s:** **SDG 3** - Good Health and Well-being (How does simulation help reduce the spread of disease?) **SDG 8** - Decent Work and Economic Growth (How can simulation help promote a safe working environment?) **SDG 9** - Industry, Innovation and Infrastructure (How the simulation results show the need for widespread use of ICT?)
Tentative new ILO	Develop model, conduct simulation and assess the impact of ICT solutions on disease spread and project risk using System Dynamics method.
Tentative new TLA**	Lecture, simulation
Tentative AT***	Simulation presentation and discussion.
Other	Students are provided with a scenario, and they then develop the model and conduct computer simulation. After the simulation is ended, the student reflects on the consequences of their choices and actions, in response to questions from teacher.

POLITO – Italy

Proposal 1 Life-Cycle Assessment

Responsible: Paolo C. Priarone

Assigned for the development: Paolo C. Priarone

Reference Program	*Management Engineering*
Reference course/s	*Sustainable Manufacturing (M.Sc. Course)*
Current ILO* /content	The course aims to provide students of the Master of Science in Management Engineering the conceptual basis and the methodological approaches related to Sustainable Manufacturing, from the guidelines to the tools for the performance analysis of a manufacturing system. This knowledge, together with the classical tools for the evaluation of efficiency, effectiveness and economy of a production system, will be necessary for the implementation of decision making strategies in sustainable production.

Description of proposed modification /addition	The teaching of the above mentioned tools could be completed and extended by applying them in real industrial cases, providing more specific skills related to the enabling technologies of Industry 4.0 to the students.
New content	**Reference Technology/ies:** Manufacturing processes, automation and robotics, **E4.** Simulation, **E6.** Additive manufacturing, **E2.** Big data and analytics. **Reference Sustainability goal/s:** **SDG 12 -** Responsible Consumption and Production
Tentative new ILO	*Knowledge*: to evaluate, in view of sustainable production, the performance of a factory through the analysis of processes and consumed resources *Skills*: • to apply sustainability indicators and criteria for analysis, • to associate them with models and analytical methods, and • to evaluate the level of performance of a company or of a production system. • to create/design procedures to improve sustainability of specific industrial problems.
Tentative new TLA	Classwork and working groups for the application of the sustainable manufacturing practices to industrial case studies (in addition to the classical frontal lectures).
Tentative AT	The exam consists of a written test containing theoretical questions (knowledge assessment), and exercises on the application of models and procedures discussed during the lectures (skills assessment).
Other	

UNILJ – Slovenia

Proposal 1 Cloud Robotics

Responsible: Primož Podržaj

Assigned for the development: Miha Finžgar, Tena Žužek, Primož Podržaj

Reference Program	*Electrical Engineering*
Reference course/s	*DD2410 Introduction to Robotics (KTH)*
Current ILO/content	https://drive.google.com/drive/u/0/folders/1INp-NGQUN_hIYRhP4DbGxG0y4ik-0Ys2
Description of proposed modification /addition	”Cloud Robotics (CR) is a rising field of robotics rooted in cloud computing, cloud storage, and other Internet technologies centered around the benefits of converged infrastructure and shared services. It allows robots to benefit from the powerful computational, storage, and communications resources of modern

	data centers. In addition, it removes overheads for maintenance and updates, and reduces dependence on custom middleware. ” [1] These characteristics are indirectly related to several UN sustainability goals (depending on their application). For more information on cloud robotics, interested readers may refer to [2]. [1] Aissam, M., Benbrahim, M., & Kabbaj, M. N. (2019). Cloud robotic: Opening a new road to the industry 4.0. In *New Developments and Advances in Robot Control* (pp. 1-20). Springer, Singapore. [2] Wan, J., Tang, S., Yan, H., Li, D., Wang, S., & Vasilakos, A. V. (2016). Cloud robotics: Current status and open issues. IEEE Access, 4, 2797-2807.
New content	**Reference Technology/ies:** **E2**. Big data & analytics – Decision making support, Data management techniques/methods **E3**. Cloud computing – Cloud manufacturing **E8**. Autonomous robots – Autonomy **Reference Sustainability goal/s:** **SDG9** - Industry, Innovation and Infrastructure
Tentative new ILO	Compare various types of communication protocols between robots and a cloud in the context of M2M interaction and select a suitable solution for a given case study scenario.
Tentative new TLA	Introduce and practically discuss (in terms of advantages and disadvantages) selected types of communication protocols between robots and a cloud (Wi-Fi, NB-IoT, Zigbee) by working with practical examples.
Tentative AT	Case study with assessment by grades - Analyse the performance (latency, bandwidth, computational power) of a data communication for a given cloud robotics example.
Other	

Proposal 2 UN SDG

Responsible: Primož Podržaj

Assigned for the development: Miha Finžgar, Tena Žužek, Primož Podržaj

Reference Program	*Mechanical Engineering*
Reference course/s	*Industrial plants, production planning and control (UNIPI) or MG2029 Production Engineering - Planning and Control (KTH)**
Current ILO /content	*MG2029 Production Engineering - Planning and Control (KTH):* https://drive.google.com/drive/u/0/folders/1INp-NGQUN_hIYRhP4DbGxG0y4ik-0Ys2
Description of proposed modification /addition	To increase the awareness of the importance of sustainability it is important to familiarize the students with the (concept of) UN SDGs. The proposed ILO can be applied to all the EPs, by simply adjusting its contents in a way that the most relevant technology-sustainability pairs (identified in MAESTRO's O1) for a given EP are emphasized in the course.
New content	**Reference Technology/ies:** **E4**. Simulation – Products and processes, Production lines, workstations and Enterprise and its operational environment. **E7**. Horizontal & Vertical System Integration – Data Modelling (Digital Twins). **Reference Sustainability goal/s:** **SDG9** - Industry, Innovation and Infrastructure **SDG12** - Responsible Consumption and Production
Tentative new ILO	Describe the activities relevant to reaching UN SDGs from the perspective of mechanical engineering. **
Tentative new TLA	Lecture on the UN SDGs with special emphasis on those SDGs that are the most relevant for mechanical engineering.
Tentative AT	Essay question exam with assessment by grades grading.
Other	

* These reference courses were selected based on the KTH's Mechanical Engineering programme and proposed courses by UNIPI.
** This ILO can also be applied to other engineering programmes (electrical, industrial, management).

Proposal 3 Machine Design (not continued in O3)

Responsible: Primož Podržaj

Assigned for the development: not continued in O3

Reference Program	*Mechanical Engineering*
Reference course/s	*Machines design (UNIPI) or MG2028 CAD and Other IT Tools in Industrial Processes (KTH)**
Current ILO/content	MG2028 CAD and Other IT Tools in Industrial Processes (KTH): https://drive.google.com/drive/u/0/folders/1INp-NGQUN_hIYRhP4DbGxG0y4ik-0Ys2
Description of proposed modification /addition	The concept of sustainable manufacturing is identified and analyzed through three main levels: product, process, and system levels. The interaction among these levels provides the required sustainable target. With regard to the product level, the perspective of sustainable manufacturing focuses on the 6R approach (i.e., re-duce, re-design, re-use, re-cover, re-manufacture, and re-cycle), as it theoretically achieves a closed loop and multiple life-cycle paradigms. (This slightly modified text was taken from [1]). The proposed ILO is directly aimed toward developing skills, and it is relevant to the suggested learning topics for SDG 12 “Responsible Consumption and Production” [2]. [1] Kishawy, H. A., Hegab, H., & Saad, E. (2018). *Design for sustainable manufacturing: Approach, implementation, and assessment.* Sustainability, 10(10), 3604. [2] Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO Publishing.
New content	**Reference Technology/ies:** **E4.** Simulation – Products and processes **E6.** Additive manufacturing – Software, Design for AM **Reference Sustainability goal/s:** **SDG 12** - Responsible Consumption and Production
Tentative new ILO	Demonstrate the capabilities of the Product Lifecycle Management (PLM) software in terms of product design. Evaluate decision-making processes in the product design from the perspective of the 6R approach.
Tentative new TLA	

Tentative AT	
Other	

Proposal 4 Engineering Planning and Control (not continued in O3)

Responsible: Primož Podržaj

Assigned for the development: not continued in O3

Reference Program	*Mechanical Engineering*
Reference course/s	*Industrial plants, production planning and control (UNIPI) or MG2029 Production Engineering - Planning and Control (KTH)**
Current ILO/content	*MG2029 Production Engineering - Planning and Control (KTH)*:* https://drive.google.com/drive/u/0/folders/1INp-NGQUN_hIYRhP4DbGxG0y4ik-0Ys2
Description of proposed modification /addition	Inclusive and sustainable innovation has four characteristics [1]: ● Such innovations add value to the life of the people much beyond the immediate use of the product or service; ● Such innovations create a product or service of an uncompromising quality at a price that is affordable; ● Such innovations address the challenge of resource use efficiency to manage drastically low cost structures; ● Such innovations are scalable and replicable to suit requirements of local circumstances and complexities. Inclusive and sustainable industrial development means [2]: ● Every country achieves a higher level of industrialization in their economies, and benefits from the globalization of markets for industrial goods and services. ● No one is left behind in benefiting from industrial growth, and prosperity is shared among women and men in all countries. ● Broader economic and social growth is supported within an environmentally sustainable framework. ● Unique knowledge and resources are combined of all relevant development actors to maximize the development impact of ISID. Inclusive and sustainable innovation and industrialization is a suggested learning topic for SDG 9 “Industry, Innovation and Infrastructure” [3]. SDG9 also reached the highest average score in MAESTRO’s O1 analysis.

	[1] Joshi, S. "Sustainable and inclusive innovation: strategies for tomorrow's world." *New Delhi, India: Confederation of Indian Industry* (2010). [2] Inclusive and Sustainable Industrial Development Forum - 2015 – IIASA. Available at: https://iiasa.ac.at/web/home/about/events/20151130_ISID1.html [3] Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO Publishing.
New content	**Reference Technology/ies:** **E4.** Simulation – Products and processes, Production lines, workstations and Enterprise and its operational environment. **E5.** Augmented reality – Simulation. **Reference Sustainability goal/s:** **SDG9** - Industry, Innovation and Infrastructure
Tentative new ILO	Argue for sustainable, resilient and inclusive infrastructure in the local area. Judge a given innovation from the point of view of sustainability and inclusiveness.
Tentative new TLA	
Tentative AT	
Other	

LBORO – United Kingdom

Proposal 1 Autonomous Robot

Responsible: Mohammed M. Mabkhot, Pedro Ferreira, Niels Lohse

Assigned for the development: Mohammed M. Mabkhot

Reference Program	*Manufacturing Engineering*
Reference course/s	*Manufacturing Automation and Control*
Current ILO* /content	Autonomous Robots knowledge and skills are not introduced in the existing ILOs.
Description of proposed	Add theoretical and practical knowledge of robotic autonomy to existing ILOs. As Autonomous robot technology is at higher maturity level, we need to introduce ILOs at

modification /addition	practical skills level. This will also require an update of existing ILOs at knowledge and cognitive skills levels.
New content	**Reference Technology/ies:** **E8.1 –** Autonomous Robots - Perception (What are the factors that determine the perception and actuation uncertainty in autonomous robot?) **E8.2 –** Autonomous Robots - Deliberation (What are the programming tools and frameworks that can be used to develop a deliberate decision making? **E8.3 –** Autonomous Robots - Autonomy (How to operate autonomous robot in real lab environment?) **Reference Sustainability goal/s:** **SDG 8** – Decent Work and Economic Growth (How Autonomous Robots can be used in hazardous and dangerous working environments? e.g., extreme temperature, radioactive, toxic, deep in water) **SDG 9** – Industry, Innovation and Infrastructure (How to use Autonomous Robots in difficult and repetitive tasks and increase the productivity and efficiency of the system?)
Tentative new ILO	- Update existing ILOs at knowledge and cognitive skills' levels to consider perception and deliberation knowledge. - Use suitable programming tool/frameworks for the development of successful autonomous robots.
Tentative new TLA**	**Additional contents:** **Classes:** - Introduce and discuss perception methods (digital cameras, GPS, lidar, sensors) and the complexity in different environment. - Introduce deliberation techniques and concepts: planning, acting, observing, monitoring, goal reasoning, and learning. **Laboratory:** Use an appropriate software to create and develop an autonomous robot logic and implement it in a lab case.
Tentative AT***	- Test the gained theoretical knowledge about perception and deliberation techniques. - Test the practical skill by (a) fill in missing parts of a logical model for an autonomous robot case (b) completing a missing part of a provided skeleton code for an autonomous robot case.
Other	

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UNIPI- Italy

Proposal 1 Additive manufacturing

Responsible: Michele Lanzetta

Assigned for the development: Michele Lanzetta, Lupi Francesco, Carmelo de Maria

Reference Program	*Mechanical engineering*
Reference course/s	*Advanced Manufacturing, Additive Manufacturing*
Current ILO* /content	Exploration of classical Manufacturing methods (cutting, milling, molding…) and Introduction to AM process
Description of proposed modification /addition	Add theoretical and practical knowledge on new AM processes/materials. Provide material and information for autonomous project work on biomedical AM prothesis.
New content	**Reference Technology/ies:** **E6.1-E6.6** - Additive Manufacturing **Reference Sustainability goal/s:** **SDG 3** - Good Health and Well-being (How the AM can improve customized medical prothesis?) **SDG 9** - Industry, Innovation and Infrastructure (How the innovations AM technology infrastructure can strengthen the medical industry?) **SDG 12** - Responsible Consumption and Production (How can AM energy and material savings and product lifecycle improve the medical industry?)
Tentative new ILO	ILO1: compare and select among classical material of additive manufactured medical prosthesis by minimizing the environmental impact ILO 2: design and optimize the environmental impact of AM processes for single medical devices production
Tentative new TLA**	Classes: -Explain theoretical topics concerning AM classical and innovative materials, environmental impact of the production processes,
Tentative AT***	Project work and oral presentation
Other	

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Proposal 2 Cobots

Responsible: Michele Lanzetta

Assigned for the development: Michele Lanzetta, Francesco Lupi, Riccardo Chelli

Reference Program	*Mechanical engineering, Industrial Engineering, Management Engineering*
Reference course/s	*Integrated Manufacturing Systems, Automation of Machining Processes, Automation and Robotics*
Current ILO* /content	Automate tasks Design an automated manufacturing plant
Description of proposed modification /addition	Automate the activities and distribute them between robot and operator, design a work cell and automated production plant in the context of human-robot collaboration, recognizes and implements the necessary workplace safety standards. **Lectures content:** Principles of automation of production processes, description of an automated work cell, examples and real applications of industrial automation; what is a collaborative robot, main characteristics and differences with traditional robots, main characteristics of collaborative end-effectors; reference standards on the safety of collaborative robots, description and implementation of the cobot safety functions, description of additional safety devices; planning of tasks within a work cell, classification of the different levels of operator-cobot collaboration, division of tasks between cobot and operator; description of real cases and examples of collaborative applications. **Laboratory classes content:** Programming of collaborative robots, analysis of operations and subdivision into logical levels (skills, tasks, primitives), differences between manual programming and through dedicated software; implementation of safety functions within the program, division of collaborative zones, setting of parameters and operating limits, setting of safety inputs; interface with the end-effector and all other devices / machines inside the work area, operator-cobot interface; programming and simulation of activities through simulation software.
New content	**Reference Technology/ies:** **E8.1-E8.3** - Collaborative Robots **Reference Sustainability goal/s**: **SDG 5** - Gender equality **SDG 8** - Decent Work and Economic Growth (How the decent work and a company development can be achieved?) **SDG 9** - Industry, Innovation and Infrastructure (How the innovations in infrastructure can strengthen the industry?)
Tentative new ILO	Design a shared space between man and robo of repetitive or dangerous manufacturing processes.
Tentative new TLA**	-Explain and detail the main theoretical topics such as principles of automation, work cell, collaborative robot, safety and ergonomic issue/standards -Practical exercise
Tentative AT***	Apply ILOs on a given case study, provide solutions, make calculations
Other	

Proposal 3 Digital lean

Responsible: Michele Lanzetta

Assigned for the development: Michele Lanzetta, Francesco Lupi

Reference Program	*Mechanical engineering, Industrial Engineering, Management Engineering*
Reference course/s	*Industrial Plants, Industrial Processes, Production Planning and Control, Quality Management*
Current ILO* /content	Apply Lean Manufacturing criteria
Description of proposed modification /addition	Digital tools for sustainability: how digital equals lean Understand SDGs Achieve an integrated view
New content	**Reference Technology/ies:** **E4.1-E.4.3** - Digital Manufacturing **E.5.5** - AR (for plant simulation) **E.1.1 – E1.6** - IOT (for distributed sensors) **Reference Sustainability goal/s**: **SDG 3** - Good Health and Well-being (How the work environment can be improved?) **SDG 9** - Industry, Innovation and Infrastructure (How the innovations in infrastructure can strengthen the industry?) **SDG 12** - Responsible Consumption and Production
Tentative new ILO	The student should be able to evaluate the economical and environmental impact of new digital technologies in the operations
Tentative new TLA**	Explain the main theoretical topics about business process mapping, lean tools and practices, i4.0 enabling technologies and sustainability
Tentative AT***	Apply ILOs on a given case study, provide solutions, make calculations
Other	

UNINOVA- Portugal

Proposal 1 Robotics systems and CIM (not continued in O3)

Responsible: Jose Barata

Assigned for the development: Jose Barata, Sanaz Nikghadam Hojjati

Reference Program	*M.Sc. Electrical and Computing Engineering*
Reference course/s	*Robotics Systems and CIM*

Current ILO* /content	1. ***Understanding***
	  1. *The complexity and importance of a manufacturing system, activities and actors*
	  2. *Importance of automation and human factor*
	  3. *Historical developments and contribution of different socio-economic environments*
	  4. *Most important requirements of today's manufacturing systems*
	  5. *Different manufacturing paradigms*
	  6. *Characteristics of reconfigurable systems*
	  7. *Meaning of complexity and self-organization*
	  8. *Importance of modelling in the context of manufacturing*
	  9. *Challenges in the implementation of Cyber-Physical Systems*
	  10. *Learning and its application in manufacturing*
	2. ***Able to Do***
	  1. *Model manufacturing systems*
	  2. *Programming intelligent control systems*
	  3. *Programming Machine Learning systems*
	3. ***Non-Technical Competences***
	  1. *Develop synthesis critical thinking*
	  2. *Team working and increasing oral and writing communication skills*
	  3. *Improve time keeping and compliance with meeting deadlines*

Description of proposed modification /addition	The current course content does not include any connection of the technology with the dimension of sustainability. We propose to add an ILO detailing such an impact using the result of O1 as basis
New content	**Reference Technology/ies:** **E1.** Industrial Internet of Things **E2.** Big Data and Analytics **E3.** Clouds computing

	E7. Horizontal and Vertical Integration **Reference Sustainability goal/s:** SDG 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all SDG 9 – Industry, innovation and infrastructure
Tentative new ILO	Student will be able to: Discuss and describe how the technologies presented during the course can be applied to support the UN SDG 8 and 9.
Tentative new TLA**	*The teacher will present the result of MAESTRO O1 and discuss the impact of the Ind 4.0 enablers relevant for the course through a series of examples.* *Students will discuss in class and create a case study for sustainable application of the technology*
Tentative AT***	*The report of the case study will be evaluated and a bonus towards the final grade awarded. Meriting reports will become part of the course material for the following year and considered for scientific publication*
Other	

Proposal 2 Cognition and autonomous systems

Responsible: Jose Barata

Assigned for the development: Jose Barata, Sanaz Nikghadam Hojjati

Reference Program	*M.Sc. Robotics and systems of intelligent manufacturing*
Reference course/s	*Cognition and autonomous systems*
Current ILO* /content	1. ***Understanding*** 1. *Autonomous Systems basic concepts* 2. *Tele Operated Systems concepts* 3. *What are architectures and the different types that characterise autonomous systems* 4. *Context Awareness and Extraction* 5. *Application of Supervised and Unsupervised Learning to Robotics* 6. *Application of Deep Learning techniques to Robotics*

	7. *The role of social implicit and explicit cues in robotics* 8. *Dynamic Task Planning and Scheduling* 9. *Mission Critical Planning* 10. *Multi-Robot Navigation and Planning* 2. ***Able to Do*** 1. *Addressing new problems and implementing strategies in the domain of robotized heterogeneous autonomous systems* 2. *Increase the capacity to practically implement robotized autonomous systems* 3. *Apply creativity and innovation* 3. ***Non-Technical Competences*** 1. *Develop synthesis critical thinking* 2. *Team working and increasing oral and writing communication skills* 3. *Improve time keeping and compliance with meeting deadlines*
Description of proposed modification /addition	The course will be expanded to include element related with alghorytms for energy efficiency in robotic as well as the importance of sustainable source of energy for the propulsion of marine autonomous robot. Special emphasis will be put on the choice of renewable source in relation with the possibility of the system to work without refuelling.
New content	**Reference Technology/ies:** **E2 Big Data and Analytics** **E8 Autonomous Robot** **Reference Sustainability goal/s:** SDG 9 SDG 11 SDG 12
Tentative new ILO	ILO 1. Describe and discuss the trade off between robot performance and energy efficiency when applied in production environment. Apply specific algorithms in real life application of robotic ILO2. Discuss the importance of renewable energy source for autonomous robot. Evaluate the impact of different energy sources for the propulsion of the robot: solar, wind and fuel cells.

Tentative new TLA**	*ILO 1. Lecture about the energy use and consumption under different operative conditions for industrial robots. Tutorial on the implementation of an energy saving algorithm connected in real time to the production daily schedule.* *Student do a project where they implement energy saving algorithm on a given case study.* *ILO 2. Lecture introducing different examples of autonomous robot and emphasizing the impact of the energy sources on the robot design and performance* *Student will analyze different technical solutions for the propulsion of marine autonomous robot and evaluate using the metrics proposed by the teacher the performance of the different systems*
Tentative AT***	*ILO 1. The report from the project will be evaluated and concur to the final grade* *ILO2. The report from the analysis will be evaluated and concur to the final grade*
Other	

Appendix 2 template for the homework in C1

Template for the ILO formulation

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Erasmus +: MAESTRO
Manufacturing Education for a Sustainable fourth Industrial Revolution
Project 2019-1-SE01-KA203-060572

Part of: Intellectual Output 3 - Workshop in Constructive Alignment

Document: Block 1 - Designing Intended Learning Outcomes

Partner: _____

	Short description	Verb (level of Understanding in the bloom Taxonomy)	Content	Context
ILO 1				
ILO 2				

Template for the TLA formulation

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Erasmus +: MAESTRO
Manufacturing Education for a Sustainable fourth Industrial Revolution
Project 2019-1-SE01-KA203-060572

Part of: Intellectual Output 3 - Workshop in Constructive Alignment

Document: Block 2: Designing Teaching and Learning Activities

Partner: _____

ILO reference (Highlight the Verb)	Teaching Activity (What the teachers do)	Learning Activity (What the students do)	How does this use the 7 Principles of good learning[3]
ILO 1	TA 1.1 TA 1.2 ….	LA 1.1 LA 1.2	
ILO 2	TA 2.1 ….	LA 2.1 ….	

[3] 7 principles of good learning:

- encourages contact between students and faculty,
- develops reciprocity and cooperation among students,
- encourages active learning,
- gives prompt feedback,
- emphasizes time on task,
- communicates high expectations
- respects diverse talents and ways of learning

Arthur W. Chickering and Zelda F. Gamson (1987)

Template for the AT formulation

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Erasmus +: MAESTRO
Manufacturing Education for a Sustainable fourth Industrial Revolution
Project 2019-1-SE01-KA203-060572

Part of: Intellectual Output 3 - Workshop in Constructive Alignment

Document: Block 3: Designing the Assessment Tasks

Partner: _____

ILO reference (Highlight the Verb)	Assessment task 1	Assessment task 2	…… AT X
ILO 1			
ILO 2			