MAESTRO

Manufacturing Education for a Sustainable fourth Industrial Revolution

Project 2019-1-SE01-KA203-060572

Output 2

Definition of new competences in the domain of Industry 4.0 for different engineering profiles

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Project Partners

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Contents

I. Document heading

Project title: **Manufacturing Education for a Sustainable fourth Industrial Revolution**

Output number: **O2**

Leading organization: **University of Pisa (UNIPI)**

Output title: **Definition of new competences in the domain of Industry 4.0 for different engineering profiles**

Authors: **University of Pisa with input from the entire consortium**

II. Intellectual Output 2 as seen in the proposal

This section presents the second intellectual output as detailed in the proposal.

A. Output Description

This activity completes the one described in O1. In detail, O2 aims at translating the suggestions produced in O1 into workable requirements to create or modify existing engineering profiles in the domain of mechanical, industrial, electrical and management engineering. The resulting profile specifications will be formulated in terms of **new learning outcomes**. The list of new learning outcomes will be open and available for universities beyond the partnership that would like to implement them or get inspiration to update their own profile.

B. Division of work

UNIPI will lead O2 and coordinate the effort of all the partners, in line with their respective expertise. As shown in Figure 1, single analyzed profiles will have a main coordinator (i.e., Mechanical engineer (UNIPI); Industrial engineer (PRZ); Electrical engineer (UNL); Management Engineer (KTH)) and sub - coordinators that will ensure synchronization of the effort.

			Mechanical engineer	**Industrial engineer**	Electrical engineer	Management Engineer
1	**KTH**	SWEDEN		KTH		**KTH**
2	**PRZ**	POLAND	PRZ	**PRZ**		
3	**LBORO**	UNITED KINGDOM		LBORO		
4	**POLITO**	ITALY, Turin			POLITO	
5	**UL**	SLOVENIA	UL		UL	
6	**UNL**	PORTUGAL			**UNL**	UNL
7	**UNIPI**	ITALY, Pisa	**UNIPI**			UNIPI

Figure 1. The coordinators and sub-coordinators of the engineering profiles

Task 2.1: Analysis of existing profiles. Each institution will analyze their own engineering profiles and identify gaps and mismatches in relation to the research diary resulting from O1.

Task 2.2: Mapping of Topic on different profiles. Following the gap and mismatch identified in Task 2.1, each profile leader (see above) will formulate a list of promising technologies to be included in an ideal instantiation of their profile. They will then coordinate the formulation of related learning outcomes as well as teaching strategies. These new learning outcomes will include requirements related to the sustainability dimension as described in the UN agenda for sustainable development.

Task 2.3: List learning outcome. A weekly online pulse meeting will be organized where a single new learning outcome will be proposed by each profile leader and discussed collegially. Learning outcome description will also include a preliminary discussion on possible teaching approach and compatibility with existing experiences.

III. Intellectual Output 2 implementation

The activity in the Intellectual Output 2 (O2) was on some extent affected by the absence of a formal definition of engineer profiles (e.g., sets of features that characterize specific engineer types) necessary for the Task 2.1 as well as the absence of a formal methodology to map SDGs onto these engineer profiles (also called engineer archetypes) necessary for Task 2.2 and 2.3. In this framework, additional preparatory work has become necessary. The consortium, led by the UNIPI team, filled the two gaps above mentioned by answering the following Research Questions (RQs) in the (new) **preparatory Task 2.0.**

- **RQ1**: How to define the engineer archetypes?
- **RQ2**: How much does a specific engineer archetype contribute to Sustainable Development?

The adaptation of activities to answer the additional constraints posed by the pandemic and the additional Task 2.0 caused intensification in the meetings but no delay in the schedule: from the planned end on 2021-07-31 the O2 activities finished on 2021-07-31.

IV. Intellectual Output 2 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 emphasis 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

V. Results of Intellectual Output 2

The Intellectual Output 2 goal was to develop new engineering learning outcome that will include requirements related to the sustainability dimension as described in the UN agenda for sustainable development. Before focusing on the actual outputs of the planned Task 2.1,2.2 and 2.3 we briefly report the answers to each RQ of the new preparatory Task 2.0. The results of Task 2.0 are summarized the first section and published in a research article (*Lupi et. al 2021*). The results of Tasks 2.1, 2.2 and 2.3 are reported in the second section.

In the following a list of acronyms used through the text is reported for better readability.

Acronym	Meaning
AM	Additive Manufacturing
AR	Augmented Reality
AT	Assessment Task
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CAPP	Computer Aided Production Planning
CL	Cluster
CMM	Coordinate Measuring Machine
CPS	Cyber Physical Systems
DSS	Decision Support Systems
ESCO	European Skills, Competences, Qualifications and Occupations
FEM	Finite Element Modeling
I4.0	Industry 4.0
ICT	Information and Communication Technology
ILO	Intended Learning Outcome
IoT	Internet of Things
ISO	International Organization for Standardization
IT	Information Technology
KPI	Key Performance Indicator
KTH	Royal Institute of Technology
LBORO	University of Loughborough
MAESTRO	Manufacturing Education for a Sustainable fourth Industrial Revolution
PLM	Product Lifecycle Management
POLITO	Politecnico di Torino
PRZ	Rzeszów University of Technology
RQ	Research question
SDG	Sustainable Development Goals
SOA	Services Oriented Architecture
SS-ILOs	Semi Structured Intended Learning Outcomes
TLA	Teaching and Learning Activities
TQM	Total Quality Management
UNILJ	University of Ljubljana
UNINOVA	Instituto Desenvolvimento de Novas Tecnologias
UNIPI	Università di Pisa
VSM	Value Stream Mapping

A. Task 2.0 results

In Figure 2 the developed methodology to define standard engineer archetypes (RQ1) and evaluate its sustainability (RQ2) is reported in the following two subsections. A specific case study of *Industrial Engineering* is also reported to validate the proposed general methodology for answering RQ1 and RQ2.

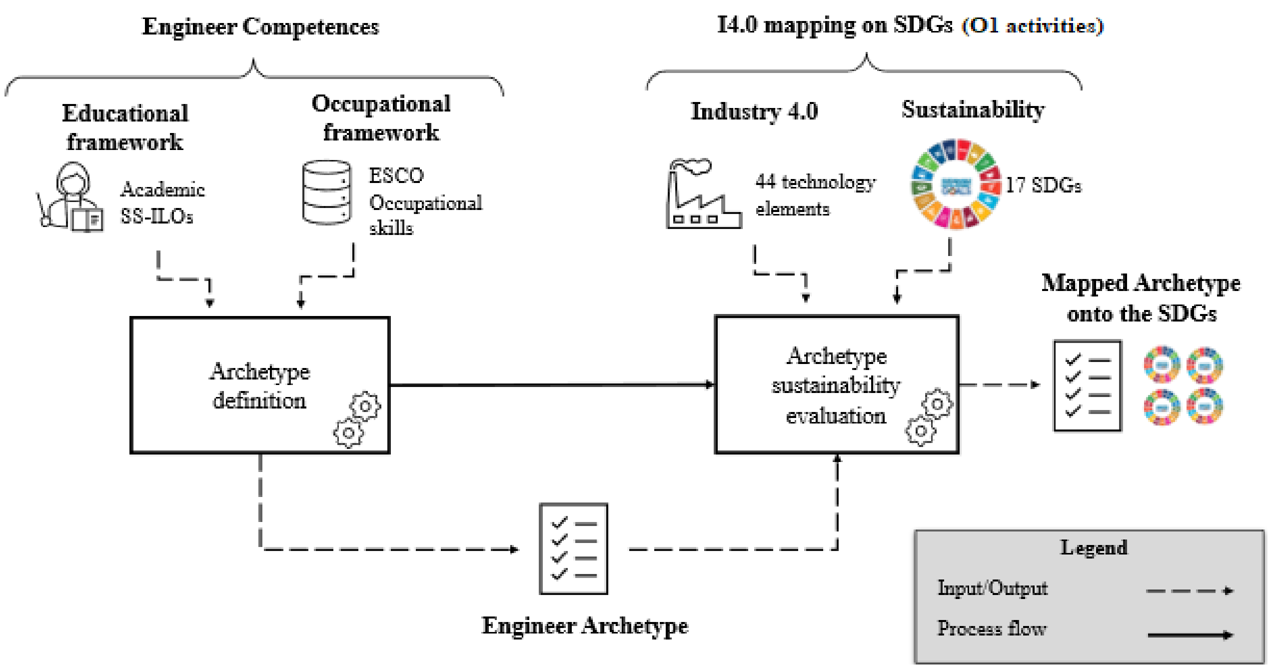

Figure 2. Flowchart of the proposed methodology to define a standard engineer archetype and assess its sustainability through the I4.0 technology elements.

RQ1 How to define the engineer archetypes?

As mentioned above, standard engineer archetypes have not yet been defined neither in the educational nor in the occupational frameworks. To answer **RQ1,** a method to provide the procedural steps for designers of learning frameworks is detailed. This guidance method helps to systematically define standard engineer archetypes through a collaborative working group. The following two types of engineering competences (academic SS-ILOs and ESCO Occupational skills) are adopted as input raw data (Figure 2, left):

I. ***Academic SS-ILOs*** are sets of Semi Structured Intended Learning Outcomes derived from the related courses syllabi of the universities program under interest. To maximize the number of SS-ILOs that characterize the archetype, we suggest accounting for all (generic and specific) master's degree courses. Basic knowledge such as math, physics, and other bachelor engineering competences are implicitly embedded in any engineer and less relevant in the characterization of a specific engineer archetype.

From a practical side, a general guideline for construct the SS-ILOs is given as follow. An ideal number of courses cannot be drafted generally. It depends on the amount of effort in extracting such information and processing time for subsequent activities. However, it is evident that the more courses are offered, the more accurate will be the final archetype. Based on experience, we believe that about 50 courses. More extensive sets duplicate the data. Given a specific course, the SS-ILOs represent a set of sentences - from two to five - depending on the number of delivered topics/credits, which sum up the primary purposes and intended outcomes that the course should achieve. For a specific course, we suggest i) relying on the three pillars of ILOs (i.e., acting *verbs, contents,* and *contexts*), ii) focusing on what the students should be able to do at the end of the course, and iii) using from 10 to 25 words. However, since the SS-ILOs are "semi structured," these three pillars' presence is not mandatory. In contrast to the high degree of formality of the well-established ILOs, this solution overcomes different degrees of formalization from diverse academic institutions. It maximizes the generation of information without significant effort, even for those having no experience in constructive alignment (*Maffei et. al 2022*).

Table 1 report a set of SS-ILOs extracted from about 50 courses in the MAESTRO consortium for a specific archetype: *industrial engineer*.

Table1. SS-ILOs from MAESTRO partners (i.e., UNIPI, POLITO, LBORO, KTH, UNILJ, PRZ, UNINOVA) Industrial engineer master's degree courses.

Courses	**SS-ILOs**
Classical Manufacturing Technology	description of different manufacturing methods: cutting,molding,deformation,welding
	processes modeling, optimization and technical economical selection
Advanced Manufacturing Technology	Select and present appropriate machining (metal cutting) and forming processes, including unconventional methods
Production Engineering - Project Course	use relevant models for developing, comparing and suggesting solutions to a production engineering problem
Industrial plants, production planning and control	Modeling, Design, optimization and use of manufacturing plant, Modelling, Design, optimization and use Logistics and Norms for safety warehouses
Production Engineering - Planning and Control	develop a production plan
Industrial Process Engineering	propose and justify solutions for design of, and work principles for machine tools and industrial robots for a flexible and resource efficient production
Non conventional manufacturing techniques	analyze advanced additive manufacturing processes and their potential for new opportunities, water jet, laser cutting, Industrial Adhesive Bonding
Prototyping methods	Select appropriate additive manufacturing processes to make physical models of products;

Courses	SS-ILOs
Advanced CAD Modeling and Rapid Prototyping, Project Course	use the full functionality of a modern CAD system to create high quality CAD models of parts with complex shapes, using a structured work method
Computer Aided Manufacturing - CAM	demonstrate practical skills in using a CAM program
Advanced CAD / CAM programming	CAM, process planning, Manufacturing Automation
Automation of machining processes	Knows the principles of building robotic stations and manufacturing systems used in technological processes, operating machine tools and technological machines
Manufacturing Automation and robotics	Collaborative robots
Automation and robotics	robot modeling and of control theory application in robotics
Automation of machining processes	Design robotic stations
Automation Technology, Advanced Course	select suitable components, control system and communication technology for automation of material handling and automated assembly
Design of machines and structure	FEM and other verification methods
Machines design	Design machine parts and prepare technical documentation with the use of selected CAD system.
Digital Factories	designing layouts of complete factories or manufacturing and assembly cells, simulations of possible layout solutions to minimize environmental impact
Modeling and Simulation of Industrial Processes	Use specific software for event-driven flow simulation to develop a balanced manufacturing flow within a factory
Applied Computer Science 6.0 credits	model real problems and implement algorithms to solve them
Lean manufacturing	Use specific software to develop factory layouts with buildings, manufacturing/assembly systems and factory assets: (DIGITAL TWIN)
Logistics & Supply Chain Management	Apply mathematical models for anticipating demand solve/optimize problems in aggregate planning, inventory management and resource exploitation
PLM - Product Lifecycle Management	explain what product data is and describe its role in a producing company through the whole life cycle of a product
	explain the basic principles of documentation of a product including the rules of operations that apply to this
	describe the main functions and the general architecture of a PLM system
Quality Control, extended course	statistical methods and tools for data analysis
Quality Control	problem solving methods and tools
	quality models (ISO, mass manufacture, TQM)
	quality enablers (design, manufacture, supply, measurement, document, staff etc.)
Advanced Metrology	Interpret tolerances in engineering drawings and use this understanding to plan and carry out measurements of given engineering components
	use different methods of measurement and understand their limitations, CMM
Modern Industrial Metrology	use statistical methods to estimate and express measurement uncertainties from the given measurement data and/or instruments and method properties
	carry out basic image processing for metrology applications
Fundamentals of electronics	Analog and digital electronics, components models, design and optimization of circuits
Modularisation of Products	suggest a proper modularisation of a product family, considering company strategies
Engines and turbo machinery	measurement and improvement of efficiency in fluido/aerodinamica combustion turbines
Mechanical materials	mechanical properties of metal (continuous) and composites

Courses	**SS-ILOs**
	modeling of behavior and design of structures
Assembly Technology	calculate the costs and the most important economical key performance indicators (KPIs) for standard assembly systems (both manual and automatic)
	choose the best sequence by applying technical and economical criteria
	create mathematical and feature models of assemblies and use them in context of design and evaluation of assembly systems

II. ***ESCO Occupational skills*** are skills that characterize the engineering archetype under interest obtained from the European Skills, Competences, Qualifications and Occupations (ESCO) database. This database offers a formal and multilingual classification for the main European professions' skills. Given a specific job, the related skills can automatically be retrieved in the database. Compared to SS-ILOs, this information set presents much more synthetic competences that often embed verbs and contents of the competence itself. For the specific case of Industrial engineering the list of skills in Table 2 are extracted.

Table2. ESCO occupational skills for the industrial engineer alphabetically ordered based on the verb.

adjust engineering designs
approve engineering design
advise architects
advise on irrigation projects
advise on pollution prevention
analyze production processes for improvement
analyze stress resistance of products
analyze test data
apply advanced manufacturing
apply medical first aid on board ship
apply technical communication skills
assemble mechatronic units
assemble robots
assess environmental impact
assess financial viability
build business relationships
calibrate mechatronic instruments
communicate using the global maritime distress and safety system
communicate with customers
conduct literature research
conduct performance tests
conduct quality control analysis
conduct training on biomedical equipment
control production
coordinate engineering teams
coordinate fire fighting
create AutoCAD drawings

create a product's virtual model
create software design
create solutions to problems
create technical plans
debug software
define manufacturing quality criteria
define technical requirements
design automation components
design electric power systems
design engineering components
design firmware
design medical devices
design prototypes
design thermal equipment
design thermal requirements
design ventilation network
determine production capacity
determine production feasibility
develop agricultural policies
develop electricity distribution schedule
develop electronic test procedures
develop mechatronic test procedures
develop medical device test procedures
develop product design
develop software prototype
develop strategies for electricity contingencies
disassemble engines
draft bill of materials
draft design specifications
ensure compliance with electricity distribution schedule
ensure compliance with environmental legislation
ensure compliance with safety legislation
ensure equipment cooling
ensure safety in electrical power operations
ensure vessel compliance with regulations
evaluate engine performance
examine engineering principles
execute analytical mathematical calculations
execute feasibility study
extinguish fires
follow company standards
follow safety standards in industrial contexts

gather technical information
inspect engine rooms
inspect facility sites
inspect overhead power lines
inspect underground power cables
install automation components
install circuit breakers
install heating boiler
install heating furnace
install heating, ventilation, air conditioning and refrigeration ducts
install mechatronic equipment
install transport equipment engines
interpret 2D plans
interpret 3D plans
interpret technical requirements
keep up with digital transformation of industrial processes
lead a team in fishery services
liaise with engineers
lubricate engines
maintain agricultural machinery
maintain control systems for automated equipment
maintain electrical equipment
maintain electronic equipment
maintain robotic equipment
maintain safe engineering watches
maintain shipboard machinery
make electrical calculations
manage electricity transmission system
manage engine-room resources
manage engineering project
manage ship emergency plans
manage supplies
manage the operation of propulsion plant machinery
manage workflow processes
manipulate medical devices' materials
manufacture medical devices
model medical devices
monitor automated machines
monitor electric generators
monitor manufacturing quality standards
monitor production developments
operate control systems

operate electronic measuring instruments
operate life-saving appliances
operate marine machinery systems
operate precision machinery
operate pumping systems
operate scientific measuring equipment
operate ship propulsion system
operate ship rescue machinery
oversee construction project
oversee quality control
perform data analysis
perform project management
perform resource planning
perform small vessel safety measures
perform small vessel safety procedures
perform test run
plan manufacturing processes
prepare assembly drawings
prepare production prototypes
prevent fires on board
program firmware
provide advice to farmers
provide advice to technicians
provide cost benefit analysis reports
provide technical documentation
provide training
re-assemble engines
read engineering drawings
read standard blueprints
record test data
repair engines
repair medical devices
replace machines
report analysis results
report test findings
research improvement of crop yields
respond to electrical power contingencies
set up automotive robot
set up the controller of a machine
simulate mechatronic design concepts
solder electronics
supervise electricity distribution operations

survive at sea in the event of ship abandonment
swim
test mechatronic units
test medical devices
test procedures in electricity transmission
train employees
troubleshoot
use CAD software
use CAM software
use a computer
use computer-aided engineering systems
use maritime English
use precision tools
use technical documentation
use testing equipment
use thermal analysis
use thermal management
use tools for construction and repair
wear appropriate protective gear
wear cleanroom suit
work in a fishery team
work in outdoor conditions
write routine reports

The elements of the two sets (Table 1 and Table 2) are thus grouped, and an initial long list of competences is obtained. After this stage, the competences are clustered through a consensus-based approach by groups of academic experts. The main task of this activity is the synthesis of the input list to a final set of 5-10 clusters of competences that cover all the identified aspects. The respective clusters of competences hence define the engineer archetype. Duplicated or overlapping courses are to be merged in a fictitious meta course that extracts the main common patterns from diverse instances (e.g., similar courses from different institutions), minimizing the information only to the necessary and sufficient. The output of this abstraction is, therefore, a consensus archetype made by a number (e.g., 5<x<10) of synthetic competence clusters denoted as CL1-CLx that allow relatively easy management for further processing (e.g., SDGs mapping on engineer archetype, see next section discussing RQ2).
The industrial engineer archetype example is summarized in Table 3.

Table3. The industrial engineer archetype and its clusters of competences.

Clusters	Summary of Competences
CL.1. Manufacturing Processes	-Design and Analyze a plan or specification for the design of classical industrial production systems (e.g., cutting, molding, deformation, welding etc.)
	-Design and Analyze nonconventional processes (e.g., advanced additive manufacturing, water jet, laser cutting, industrial adhesive bonding etc.)
	-Design and Analyze the best suited assembly technology applying technical and economic criteria.
	-Use specific software for event-driven flow simulation to develop a balanced manufacturing flow within a factory
	-Use specific software to develop factory layouts with buildings, manufacturing/assembly systems and factory assets.
CL.2. Design of machines, structures, and products	-Research on and design of machines and mechanical installations, components, or testing prototypes using CAE tools.
	-Prepare drawing and technical documentation by applying standards and engineering principles.
	-Analyze the ability of materials to endure stress imposed by temperature, loads, motion, vibration, and other factors using mathematical formulae and simulations.
	-Conduct research and experiments.
CL.3. Production IT Tools infrastructure	-Practical skills in using CAE software for integrated manufacturing systems (e.g., CAD-CAPP-CAM).
	-Evaluate and Select optimal IT solutions to integrate with hardware systems.
	-Compare and assess ICT products and service in terms of quality, costs, and compliance to specifications.
	-Design/Select of an optimal PLM system for product data control.
CL.4. Manufacturing Automation and robotics	-Apply robot modeling and control theory in robotics stations as well as design and build manufacturing systems.
	-Select of suitable components, control system and communication technology for automation of material handling and automated assembly.
	-Assemble robotic machines, devices, and components according to engineering drawings.
	-Program and install the necessary components of robotic systems, such as robot controllers, conveyors, and end-of-arm tools.
CL.5. Production Planning and Control	-Design and optimization of production planning and adjust work schedule to maintain permanent shift operation.
	-Plan maintenance processes to ensure satisfactory performance and compliance with specifications and regulations.
	-Use of statistical methods and tools for process monitoring and product measurements.
	-Apply of integrated HSE systems (ISO 9001, 14001, 45001 and other standard)
	-Improve production rates, efficiencies, yields, costs, and changeovers of products and processes.
	-Plan, monitor and report on the budget.
CL.6. Logistics & Supply Chain Management	-Apply mathematical models for anticipating demand, solve/optimize problems in aggregate planning, inventory management and resource exploitation.
	-Monitor and control the flow of supplies that includes the purchase, storage, and movement of the required quality of raw materials, and work-in-progress inventory.
	-Manage supply chain activities and synchronize supply with demand of production and customer.

RQ2 How much does a specific engineer archetype contribute to Sustainable Development?

The relation between the archetypes and SDGs is complicated and cannot be assessed straightforwardly. Therefore, the assessment is regarding the competences of a specific type of engineer with respect to I4.0 technologies indirectly exploiting the result of mapping the I4.0 technology elements into the SDGs as detailed in O1 activities (Figure 2, right) and reported in the related scientific article (MM Mabkhot et al. 2022). As shown in Figure 3, the archetype and its contribution to each SDG passing through I4.0 technology elements are summarized by the **A** matrix (Figure 4) having E1.1-E9.2 rows and SDG1-SDG17 columns (Table 4 and Table 5).

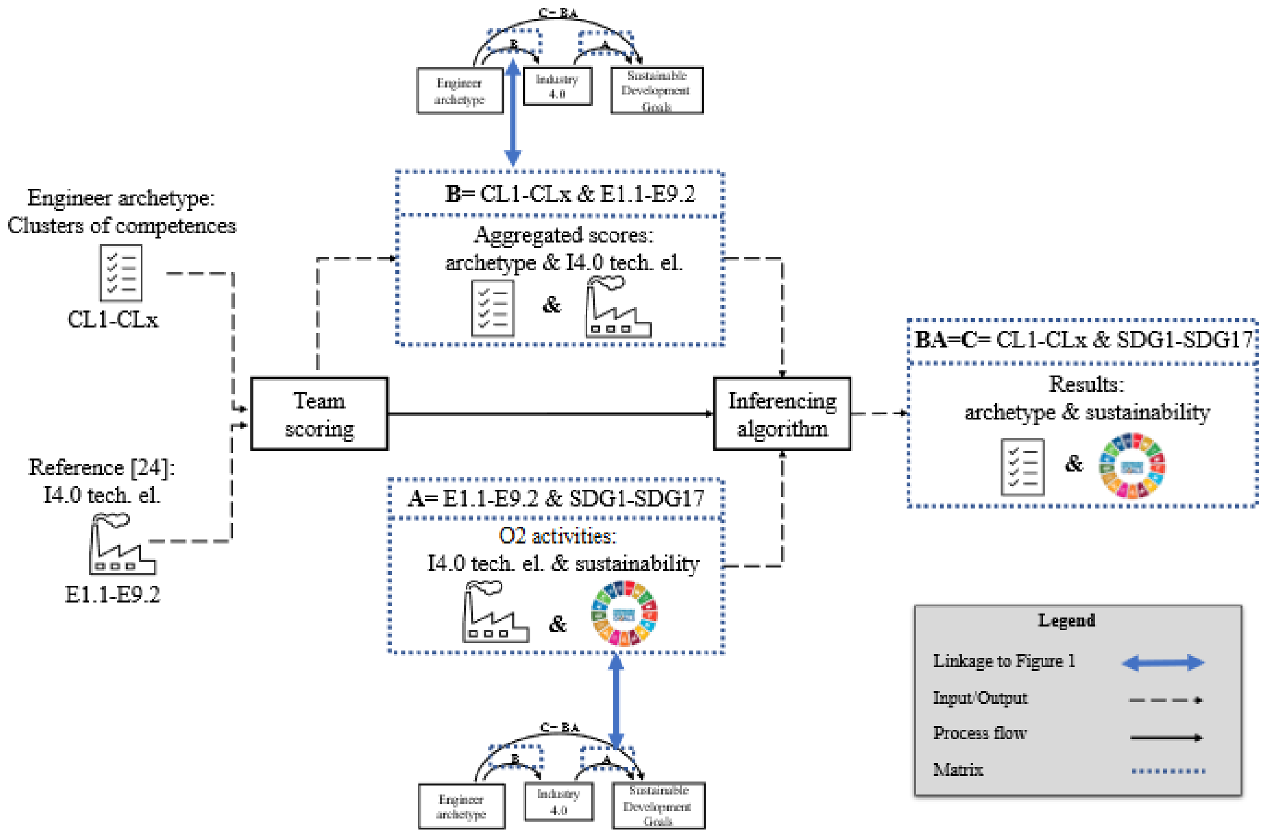

Figure 3. Outline of the proposed method for the sustainability evaluation of the engineer archetype.

A			Sustainable Development Goals																
			SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
Industry 4.0	E1	E1.1	0,24	0,29	0,57	0,24	0,10	0,29	0,33	0,38	0,90	0,19	0,52	0,48	0,33	0,29	0,33	0,10	0,24
		E1.2	0,24	0,38	0,62	0,10	0,10	0,38	0,33	0,29	0,81	0,10	0,71	0,57	0,33	0,33	0,43	0,10	0,14
		E1.3	0,24	0,38	0,57	0,43	0,05	0,33	0,43	0,43	0,90	0,05	0,81	0,62	0,14	0,10	0,19	0,10	0,19
		E1.4	0,19	0,14	0,67	0,48	0,05	0,48	0,48	0,33	0,90	0,00	0,57	0,52	0,38	0,38	0,38	0,24	0,19
		E1.5	0,33	0,33	0,67	0,43	0,14	0,38	0,48	0,48	0,90	0,19	0,81	0,57	0,33	0,29	0,29	0,33	0,33
		E1.6	0,14	0,14	0,43	0,24	0,05	0,29	0,33	0,29	0,71	0,05	0,67	0,38	0,24	0,14	0,19	0,14	0,24
	E2	E2.1	0,24	0,33	0,76	0,10	0,14	0,62	0,48	0,38	0,81	0,10	0,71	0,57	0,62	0,52	0,52	0,19	0,10
		E2.2	0,43	0,52	0,67	0,52	0,24	0,62	0,62	0,52	0,71	0,29	0,81	0,48	0,71	0,52	0,38	0,33	0,29
		E2.3	0,38	0,48	0,67	0,48	0,33	0,62	0,62	0,48	0,71	0,33	0,81	0,57	0,67	0,57	0,43	0,43	0,48
		E2.4	0,38	0,48	0,57	0,48	0,24	0,48	0,38	0,33	0,62	0,19	0,52	0,52	0,48	0,38	0,33	0,33	0,33
		E2.5	0,33	0,24	0,67	0,62	0,29	0,62	0,43	0,52	0,81	0,24	0,62	0,52	0,57	0,48	0,33	0,33	0,33
		E2.6	0,38	0,57	0,67	0,52	0,33	0,71	0,62	0,19	0,81	0,19	0,81	0,57	0,62	0,52	0,38	0,33	0,38
		E2.7	0,71	0,81	0,76	0,62	0,33	0,81	0,71	0,52	0,90	0,38	1,00	0,57	0,71	0,62	0,48	0,43	0,48
		E2.8	0,38	0,48	0,57	0,43	0,29	0,62	0,62	0,52	0,81	0,48	0,71	0,48	0,52	0,38	0,38	0,33	0,33
	E3	E3.1	0,33	0,29	0,33	0,38	0,05	0,14	0,29	0,05	0,90	0,10	0,67	0,52	0,14	0,10	0,10	0,19	0,38
		E3.2	0,14	0,24	0,29	0,19	0,05	0,24	0,38	0,33	0,90	0,00	0,76	0,43	0,14	0,10	0,10	0,33	0,52
		E3.3	0,10	0,10	0,24	0,48	0,05	0,10	0,48	0,52	0,90	0,29	0,62	0,57	0,24	0,05	0,05	0,19	0,38
		E3.4	0,14	0,05	0,05	0,24	0,00	0,05	0,33	0,33	1,00	0,10	0,33	0,43	0,19	0,00	0,00	0,14	0,29
	E4	E4.1	0,14	0,05	0,33	0,43	0,05	0,33	0,38	0,62	0,90	0,10	0,43	0,62	0,24	0,19	0,14	0,05	0,05
		E4.2	0,14	0,10	0,43	0,29	0,05	0,14	0,38	0,57	0,81	0,10	0,38	0,71	0,14	0,00	0,05	0,00	0,00
		E4.3	0,05	0,10	0,48	0,29	0,05	0,29	0,43	0,62	0,81	0,05	0,43	0,57	0,19	0,10	0,10	0,00	0,10
	E5	E5.1	0,05	0,10	0,48	0,81	0,24	0,05	0,14	0,62	0,90	0,14	0,14	0,24	0,24	0,14	0,14	0,00	0,00
		E5.2	0,14	0,10	0,52	0,81	0,38	0,05	0,10	0,71	0,90	0,19	0,43	0,48	0,29	0,29	0,29	0,14	0,29
		E5.3	0,24	0,10	0,52	0,90	0,33	0,05	0,29	0,71	0,81	0,24	0,43	0,43	0,29	0,19	0,19	0,05	0,19
		E5.4	0,10	0,05	0,52	0,71	0,19	0,10	0,19	0,52	0,81	0,19	0,48	0,57	0,38	0,33	0,33	0,19	0,24
		E5.5	0,05	0,05	0,48	0,71	0,24	0,05	0,19	0,52	0,81	0,14	0,29	0,38	0,29	0,24	0,29	0,05	0,00
	E6	E6.1	0,00	0,00	0,38	0,10	0,05	0,24	0,24	0,19	1,00	0,14	0,24	0,43	0,24	0,14	0,19	0,00	0,00
		E6.2	0,00	0,00	0,38	0,05	0,05	0,24	0,24	0,19	1,00	0,14	0,24	0,48	0,24	0,05	0,10	0,00	0,00
		E6.3	0,00	0,00	0,38	0,05	0,05	0,24	0,33	0,19	0,90	0,14	0,29	0,43	0,10	0,00	0,05	0,00	0,00
		E6.4	0,10	0,10	0,48	0,10	0,10	0,29	0,33	0,29	0,90	0,14	0,29	0,43	0,19	0,14	0,19	0,00	0,00
		E6.5	0,00	0,00	0,38	0,10	0,05	0,05	0,14	0,29	0,71	0,05	0,14	0,29	0,05	0,00	0,05	0,00	0,00
		E6.6	0,00	0,00	0,29	0,10	0,05	0,05	0,14	0,29	0,71	0,05	0,10	0,29	0,05	0,00	0,00	0,00	0,00
	E7	E7.1	0,05	0,10	0,10	0,05	0,00	0,19	0,24	0,19	0,71	0,05	0,29	0,52	0,05	0,00	0,05	0,00	0,19
		E7.2	0,10	0,10	0,19	0,14	0,00	0,14	0,24	0,38	0,81	0,00	0,14	0,48	0,05	0,05	0,05	0,00	0,05
		E7.3	0,14	0,19	0,48	0,24	0,05	0,19	0,38	0,57	1,00	0,10	0,57	0,62	0,24	0,19	0,24	0,14	0,33
		E7.4	0,14	0,19	0,33	0,29	0,05	0,24	0,43	0,48	1,00	0,05	0,48	0,57	0,14	0,14	0,19	0,14	0,29
		E7.5	0,14	0,14	0,48	0,38	0,10	0,24	0,38	0,52	1,00	0,05	0,48	0,57	0,33	0,19	0,19	0,14	0,38
		E7.6	0,10	0,10	0,38	0,24	0,05	0,19	0,33	0,43	0,81	0,05	0,38	0,52	0,24	0,19	0,19	0,05	0,29
		E7.7	0,48	0,52	0,43	0,38	0,14	0,29	0,52	0,43	0,90	0,24	0,71	0,52	0,24	0,29	0,19	0,33	0,57
	E8	E8.1	0,14	0,48	0,52	0,14	0,19	0,14	0,19	0,33	0,81	0,00	0,38	0,33	0,29	0,33	0,29	0,14	0,14
		E8.2	0,14	0,38	0,52	0,24	0,29	0,24	0,29	0,33	0,81	0,00	0,38	0,33	0,29	0,33	0,29	0,14	0,14
		E8.3	0,19	0,43	0,62	0,24	0,10	0,10	0,14	0,33	0,76	-0,1	0,43	0,24	0,24	0,24	0,24	0,05	0,05
	E9	E9.1	0,10	0,10	0,43	0,24	0,05	0,24	0,19	0,29	0,62	0,05	0,62	0,38	0,05	0,05	0,05	0,33	0,33
		E9.2	0,10	0,10	0,43	0,19	0,05	0,29	0,24	0,29	0,62	0,05	0,62	0,43	0,19	0,14	0,14	0,33	0,33

Figure 4. The A matrix from O1.

Table 4. The I4.0 enablers and the technology elements as defined in O1.

Enablers	Technology elements (sub-enablers)
E1. Industrial Internet of Things	E1.1. General Identification
	E1.2. Ubiquitous Sensing
	E1.3. Seamless & high speed Communication
	E1.4. Embedded & Edge Computation
	E1.5. Services Oriented Architecture (SOA)
	E1.6. Interoperable Semantics Communication
E2. Big Data & analytics	E2.1. Sensors
	E2.2. Data collecting
	E2.3. Data processing
	E2.4. Data querying
	E2.5. Data access
	E2.6. Data analytics
	E2.7. Decision-making support
	E2.8. Data management techniques/ methods
E3. Cloud Computing	E3.1. Computing
	E3.2. Interoperability
	E3.3. Servicelisation (on the Cloud)
	E3.4. Cloud Manufacturing
E4. Simulation	E4.1. Products and processes
	E4.2. Production lines, workstations and internal logistics
	E4.3. Enterprise and its operational environment
E.5 Augmented Reality	E5.1. Machine interaction
	E5.2. Human interaction
	E5.3. Training
	E5.4. Communication
	E5.5 Simulation
E6. Additive Manufacturing	E6.1. Processes for polymers
	E6.2. Processes metals
	E6.3. Processes for ceramics
	E6.4. Materials
	E6.5. Design for AM
	E6.6. Software
E7. Horizontal & Vertical System Integration	E7.1. Reference Architectures
	E7.2. RAMI 4.0
	E7.3. Systems Integration
	E7.4. Data Modeling (Digital Twins)
	E7.5. CPS
	E7.6. Systems of Systems
	E7.7. Collaborative Networks
E8. Autonomous Robots	E8.1. Perception
	E8.2. Deliberation
	E8.3. Autonomy
E9. Cybersecurity	E9.1. Threat identification and detection
	E9.2. Data loss prevention

Table 5. The SDGs as defined by UN

Goal	Summary Description
SDG1: No Poverty	End poverty in all its forms everywhere
SDG2: Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
SDG3: Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages
SDG4: Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG5: Gender Equality	Achieve gender equality and empower all women and girls
SDG6: Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all
SDG7: Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG8: Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
SDG9: Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
SDG10: Reduced Inequality	Reduce inequality within and among countries
SDG11: Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient and sustainable
SDG12: Responsible Consumption and Production	Ensure sustainable consumption and production patterns
SDG13: Climate Action	Take urgent action to combat climate change and its impacts
SDG14: Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG15: Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG16: Peace and Justice Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
SDG17: Partnerships to achieve the Goal	Strengthen the means of implementation and revitalize the global partnership for sustainable development

The assessment is done in two consecutive steps:

I. The ***team scoring*** activity involves assessing the I4.0 technology elements consideration in the archetypes (Figure 3, left). First, the I4.0 technology elements in the archetype are evaluated by a panel of experts. Then, each member of the panel assigns a score for each cluster of competences (CL1-CLx), identified in the previous step, into the 44 technology elements (E1.1-E9.2) (Table 4). A four ordinal correlation measure is used: no correlation, weak, high, and very high correlation that correspond to four possible scores 0, 1, 3 and 9, respectively; then, the average values from the panel of experts are computed. The result obtained is the **B** matrix having CL1-CLx rows and E1.1.-E9.2 column. The specific example for industrial engineering is reported in Figure 5. The template developed for the team scoring is reported in Appendix 1.

B		Industry 4.0													
		E1						E2							
		E1.1	E1.2	E1.3	E1.4	E1.5	E1.6	E2.1	E2.2	E2.3	E2.4	E2.5	E2.6	E2.7	E2.8
Industrial Engineer Archetype	CL1	1,00	3,00	2,25	2,25	0,75	0,75	1,50	0,75	0,75	0,25	0,25	0,75	4,50	0,75
	CL2	0,75	0,25	0,75	1,00	0,25	0,25	2,75	1,00	0,75	0,75	0,75	2,25	2,25	2,50
	CL3	4,00	1,50	5,25	5,25	1,00	0,75	3,25	3,75	1,50	3,75	3,25	3,00	3,00	3,25
	CL4	7,00	2,25	3,75	3,25	1,75	1,75	3,75	3,25	1,50	1,00	1,00	2,25	4,75	1,00
	CL5	1,75	1,00	0,25	0,75	0,25	0,75	3,00	3,25	5,50	0,75	0,75	6,00	7,00	1,50
	CL6	3,25	1,00	1,00	0,25	1,00	0,25	1,00	4,75	5,00	0,25	0,25	3,00	4,75	2,75

B		Industry 4.0											
		E3				E4			E5				
		E3.1	E3.2	E3.3	E3.4	E4.1	E4.2	E4.3	E5.1	E5.2	E5.3	E5.4	E5.5
Industrial Engineer Archetype	CL1	0,75	0,25	0,75	0,75	7,00	6,00	3,50	0,75	0,50	2,50	0,75	2,50
	CL2	2,50	0,75	0,25	0,75	6,00	3,75	1,75	3,00	1,00	0,50	1,00	5,25
	CL3	4,00	5,25	5,00	3,50	6,00	4,50	3,25	1,50	1,75	3,25	5,25	5,25
	CL4	2,25	0,75	0,75	1,00	3,00	3,00	3,00	1,00	0,75	0,75	2,25	2,25
	CL5	0,25	0,25	0,25	0,25	5,50	4,00	4,00	0,25	0,25	1,00	0,25	0,25
	CL6	0,75	0,25	1,50	0,75	2,00	7,00	1,75	0,25	1,00	0,50	1,00	1,00

B		Industry 4.0																	
		E6						E7							E8			E9	
		E6.1	E6.2	E6.3	E6.4	E6.5	E6.6	E7.1	E7.2	E7.3	E7.4	E7.5	E7.6	E7.7	E8.1	E8.2	E8.3	E9.1	E9.2
Industrial Engineer Archetype	CL1	7,00	7,50	5,50	4,00	3,50	3,00	0,25	0,25	0,75	1,00	0,25	0,75	0,75	1,00	1,00	1,00	0,33	0,25
	CL2	2,75	2,75	2,75	5,00	7,50	4,50	0,25	0,25	0,25	0,50	0,75	0,75	0,75	0,75	0,75	0,75	0,25	0,25
	CL3	1,75	1,25	1,25	0,25	4,50	3,75	5,50	3,00	7,50	5,50	4,00	4,50	1,50	0,75	0,75	0,75	3,50	3,50
	CL4	0,25	0,25	0,25	0,25	1,00	1,00	2,50	0,50	1,50	1,00	3,00	1,50	0,50	6,00	6,00	7,50	1,00	1,00
	CL5	1,00	1,00	1,00	1,00	1,00	0,25	1,00	0,50	5,50	4,75	0,75	1,00	0,75	0,25	0,25	0,75	0,25	0,25
	CL6	0,25	0,25	0,25	0,25	0,25	0,25	1,00	0,50	1,25	0,25	1,00	1,00	2,25	0,50	0,50	0,33	0,50	0,50

Figure 5. The B matrix for the industrial engineer archetype example. The results are aggregated from the MAESTRO members (UNIPI, POLITO, LBORO, KTH, UNILJ, PRZ) evaluations.

II. The ***inferencing algorithm*** is based on the well-known matrix product that works for those matrices that share the same number of rows and columns. The only alteration is to compute a weighted mean, instead of the classical summation, for each output element of the final matrix. Since the two matrices **B** = CL1-CLx & E1.1.-E9.2 and **A** = E1.1- E9.2 & SDG1-SDG12 share the I4.0 technology elements dimension (i.e., E1.1-E9.2), an algebraic product operator can be used. The inferencing algorithm used the team scoring result (matrix **B**) to deduce the sustainability relation via the mapping result in O1 activities (matrix **A**). The final matrix **C=BA=** CL1-CLx & SDG1-SDG17 thus bridges the CL1-CLx (i.e., the engineer archetype) to each of the 17 SDGs. Each element **C***i,j* is the weighted average of the products as recalled in the algorithm below:

```
for j=1 to X [or CL1-CLx]
      for k=1 to 17 [or SDG1-SDG17]
           for i=1 to 44 [or E1.1-E9.2]
                 sum1=sum1 + (Bj,i * Ak,i)
                 sum2= sum2 + (Bj,i)
           end
           The CLj impact onto SDGk is computed as the
           weighted mean, thus Cj,k  = sum1/sum2
      end
     plot the CLj radar diagram by using Cj values
end
```

For completeness the matrix C for industrial engineer case study is reported in Figure 6.

C		Sustainable Development Goals																
		SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
Industrial Engineer Archetype	CL1	0,15	0,16	0,46	0,29	0,11	0,28	0,34	0,39	0,87	0,13	0,43	0,49	0,26	0,18	0,19	0,09	0,12
	CL2	0,15	0,16	0,46	0,33	0,12	0,26	0,32	0,40	0,84	0,13	0,41	0,46	0,26	0,19	0,19	0,10	0,12
	CL3	0,18	0,20	0,45	0,36	0,11	0,27	0,36	0,42	0,84	0,12	0,51	0,51	0,28	0,21	0,20	0,16	0,23
	CL4	0,21	0,30	0,53	0,34	0,14	0,31	0,36	0,41	0,83	0,10	0,54	0,48	0,32	0,27	0,26	0,16	0,21
	CL5	0,26	0,31	0,53	0,37	0,16	0,41	0,46	0,45	0,85	0,17	0,60	0,55	0,38	0,30	0,27	0,19	0,25
	CL6	0,28	0,32	0,53	0,40	0,17	0,38	0,45	0,46	0,83	0,19	0,61	0,54	0,39	0,30	0,26	0,20	0,26

Figure 6. The C matrix for the industrial engineer archetype example.

B. Task 2.1, 2.2 and 2.3 results

This section introduces the Candidate Educational Units from each partner that have been extracted during the Tasks 2.1, 2.2. and 2.3 and using as a reference the procedure proposed to define the engineer archetype profile. The candidate educational units in output from this section will be used as the basis for the development in O3. Template used for this activity is reported in Appendix 2. Each institution proposals are reported as follows:

- KTH: 2 proposals
- PRZ: 3 proposals
- POLITO: 1 proposal
- UNILJ: 4 proposals
- LBORO: 1 proposal
- UNINOVA: 2 proposal
- UNIPI: 3 proposals

Please note that in all the following tables we used the following abbreviations (as stated in the initial paragraph of Section V.)

* Intended Learning Outcome=ILO

** Teaching and Learning Activities=TLA

*** Assessment Task=AT

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 environment using AR applications?) **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 the upgrade of technological capabilities can 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**	*What Kind of activities would be good to enable a proper learning process for the related ILO* • 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***	*what kind of exam or other form of verification of knowledge would suit the assessment of the proposed ILO* 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**	*What Kind of activities would be good to enable a proper learning process for the related ILO* **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***	*what kind of exam or other form of verification of knowledge would suit the assessment of the proposed ILO* 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 modification /addition	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 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**	*What Kind of activities would be good to enable a proper learning process for the related ILO* Lecture, simulation
Tentative AT***	*what kind of exam or other form of verification of knowledge would suit the assessment of the proposed ILO* 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:** **E6** - Additive manufacturing **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: Primož Podržaj, Miha Finžgar

Reference Program	*Electrical Engineering*
Reference course/s	*DD2410 Introduction to Robotics (KTH)*
Current ILO/content	Cloud robotics related knowledge and skills are not introduced in the existing ILOs.
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:** **SDG 9** - Industry, Innovation and Infrastructure
Tentative new ILO	Compare various types of communication protocols between robots and a cloud in the context of M2M interaction.
Tentative new TLA	Classwork and working groups working on problems provided by the industrial partners.
Tentative AT	The exam consists of a written test and oral presentation on the selected problem.
Other	

Proposal 2 UN SDG

Responsible: Primož Podržaj

Assigned for the development: Primož Podržaj, Miha Finžgar

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	UN SDG related knowledge and skills are not introduced in the existing ILOs.
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** - Industry Horizontal & Vertical System Integration – Data Modeling (Digital Twins). **Reference Sustainability goal/s:** Emphasis on: **SDG 9** - Industry, Innovation and Infrastructure) and **SDG 12** - Responsible Consumption and Production.
Tentative new ILO	Interpret the importance of relevant UN SDGs from the perspective of mechanical engineering.
Tentative new TLA	Discussions related to UN SDG topics with regard to Industrial applications.
Tentative AT	Part of the exam is a written report and subsequent presentation.
Other	

Proposal 3 Machine Design

Responsible: Primož Podržaj

Assigned for the development: Primož Podržaj, Miha Finžgar

Reference Program	*Mechanical Engineering*
Reference course/s	*Machines design (UNIPI) or MG2028 CAD and Other IT Tools in Industrial Processes (KTH)**
Current ILO/content	Understand the operational principles of building blocks of complex machinery. Utilize appropriate CAD tools to effectively design appropriate parts/products in various fields of mechanical engineering.
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	Visits of companies that produce machine parts and get familiar with the production in order to design the machine parts more effectively.
Tentative AT	Part of the grade is obtained based on the design of a specific purpose machine part.
Other	

Proposal 4 Engineering Planning and Control

Responsible: Primož Podržaj

Assigned for the development: Primož Podržaj, Miha Finžgar

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	Get familiar with all the aspects of modern Production planning and control. Utilize the appropriate software packages efficiently.
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. **E4** - Augmented reality – Simulation. **Reference Sustainability goal/s:** **SDG 9** - 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	Classwork and working groups working on problems provided by the industrial partners.
Tentative AT	The exam consists of a written test and oral presentation on the selected problem.
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 modification /addition	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 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	

UNINOVA –Portugal

Proposal 1 Energy efficiency in robotics

Responsible: Jose Barata

Assigned for the development: Jose Barata

Reference Program	*M.Sc. Robotics and systems of intelligent manufacturing*
Reference course/s	*Cognition and autonomous systems*
Current ILO* /content	1. Understanding Autonomous Systems basic concepts Tele Operated Systems concepts What are architectures and the different types that characterise autonomous systems Context Awareness and Extraction Application of Supervised and Unsupervised Learning to Robotics Application of Deep Learning techniques to Robotics The role of social implicit and explicit cues in robotics Dynamic Task Planning and Scheduling Mission Critical Planning Multi-Robot Navigation and Planning 2. Able to Do Addressing new problems and implementing strategies in the domain of robotized heterogeneous autonomous systems Increase the capacity to practically implement robotized autonomous systems Apply creativity and innovation 3. Non-Technical Competences Develop synthesis critical thinking Team working and increasing oral and writing communication skills 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 Robots **Reference Sustainability goal/s:** **SDG 9** – Industry, Innovation and Infrastructure **SDG 11** – Sustainable Cities and Communities **SDG 12** – Responsible Consumption and Production
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	

Proposal 2 Robotics Systems

Responsible: Jose Barata

Assigned for the development: Jose Barata

Reference Program	*M.Sc. Electrical and Computing Engineering*
Reference course/s	*Robotics Systems and CIM*
Current ILO* /content	1. Understanding The complexity and importance of a manufacturing system, activities and actors Importance of automation and human factor Historical developments and contribution of different socio-economic environments Most important requirements of today's manufacturing systems Different manufacturing paradigms Characteristics of reconfigurable systems Meaning of complexity and self-organization Importance of modelling in the context of manufacturing Challenges in the implementation of Cyber-Physical Systems Learning and its application in manufacturing 2. Able to Do Model manufacturing systems Programming intelligent control systems Programming Machine Learning systems 3. Non-Technical Competences Develop synthesis critical thinking Team working and increasing oral and writing communication skills 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	

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 AM energy and material savings and product lifecycle can improve the medical industry?)
Tentative new ILO	Selection of propter material for additive manufactured medical prosthesis by maximizing the efficiency of the production process. The students will develop a project work to 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	

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**- 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 robot 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	

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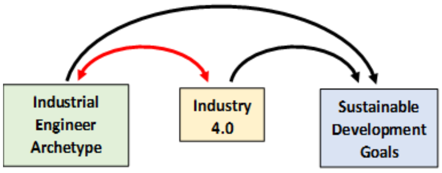
Appendix 1 template for task 2.0

Template for the archetype scoring



Please fill the empty cell by using the following weight scale for the correlation (0 no correlation, 1 weak, 3 high and 9 very high) of each competence (CL.1.-CL.6) on I4.0 sub-enabler (E1.1-E9.2)

NOTE1: I will average all the score for the final mapping. Please send the filled file where "XXX" in the name stand for the institution e.g. "LOBORO", "KTH"...etc.

Industrial Engineer Archetype						Industry 4.0		Sustainable Development Goals																
CL.1.	CL.2.	CL.3.	CL.4.	CL.5.	CL.6.			SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
						E1	E1.1.	0,24	0,29	0,57	0,24	0,10	0,29	0,33	0,38	0,90	0,19	0,52	0,48	0,33	0,29	0,33	0,10	0,24
							E1.2.	0,24	0,38	0,62	0,10	0,10	0,38	0,33	0,29	0,81	0,10	0,71	0,57	0,33	0,33	0,43	0,10	0,14
							E1.3.	0,24	0,38	0,57	0,43	0,05	0,33	0,43	0,43	0,90	0,05	0,81	0,62	0,14	0,10	0,19	0,10	0,19
							E1.4.	0,19	0,14	0,67	0,48	0,05	0,48	0,48	0,33	0,90	0,00	0,57	0,52	0,38	0,38	0,38	0,24	0,19
							E1.5.	0,33	0,33	0,67	0,43	0,14	0,38	0,48	0,48	0,90	0,19	0,81	0,57	0,33	0,29	0,29	0,33	0,33
							E1.6.	0,14	0,14	0,43	0,24	0,05	0,29	0,33	0,29	0,71	0,05	0,67	0,38	0,24	0,14	0,19	0,14	0,24
						E2	E2.1.	0,24	0,33	0,76	0,10	0,14	0,62	0,48	0,38	0,81	0,10	0,71	0,57	0,62	0,52	0,52	0,19	0,10
							E2.2.	0,43	0,52	0,67	0,52	0,24	0,62	0,62	0,52	0,71	0,29	0,81	0,48	0,71	0,52	0,38	0,33	0,29
							E2.3.	0,38	0,48	0,67	0,48	0,33	0,62	0,62	0,48	0,71	0,33	0,81	0,57	0,67	0,57	0,43	0,43	0,48
							E2.4.	0,38	0,48	0,57	0,48	0,24	0,48	0,38	0,33	0,62	0,19	0,52	0,52	0,48	0,38	0,33	0,33	0,33
							E2.5.	0,33	0,24	0,67	0,62	0,29	0,62	0,43	0,52	0,81	0,24	0,62	0,52	0,57	0,48	0,33	0,33	0,33
							E2.6.	0,38	0,57	0,67	0,52	0,33	0,71	0,62	0,19	0,81	0,19	0,81	0,57	0,62	0,52	0,38	0,33	0,38
							E2.7.	0,71	0,81	0,76	0,62	0,33	0,81	0,71	0,52	0,90	0,38	1,00	0,57	0,71	0,62	0,48	0,43	0,48
							E2.8.	0,38	0,48	0,57	0,43	0,29	0,62	0,62	0,52	0,81	0,48	0,71	0,48	0,52	0,38	0,38	0,33	0,33
						E3	E3.1.	0,33	0,29	0,33	0,38	0,05	0,14	0,29	0,05	0,90	0,10	0,67	0,52	0,14	0,10	0,10	0,19	0,38
							E3.2.	0,14	0,24	0,29	0,19	0,05	0,24	0,38	0,33	0,90	0,00	0,76	0,43	0,14	0,10	0,10	0,33	0,52
							E3.3.	0,10	0,10	0,24	0,48	0,05	0,10	0,48	0,52	0,90	0,29	0,62	0,57	0,24	0,05	0,05	0,19	0,38
							E3.4.	0,14	0,05	0,05	0,24	0,00	0,05	0,33	0,33	1,00	0,10	0,33	0,43	0,19	0,00	0,00	0,14	0,29
						E4	E4.1	0,14	0,05	0,33	0,43	0,05	0,33	0,38	0,62	0,90	0,10	0,43	0,62	0,24	0,19	0,14	0,05	0,05
							E4.2	0,14	0,10	0,43	0,29	0,05	0,14	0,38	0,57	0,81	0,10	0,38	0,71	0,14	0,00	0,05	0,00	0,00
							E4.3	0,05	0,10	0,48	0,29	0,05	0,29	0,43	0,62	0,81	0,05	0,43	0,57	0,19	0,10	0,10	0,00	0,10
						E5	E5.1	0,05	0,10	0,48	0,81	0,24	0,05	0,14	0,62	0,90	0,14	0,14	0,24	0,24	0,14	0,14	0,00	0,00
							E5.2	0,14	0,10	0,52	0,81	0,38	0,05	0,10	0,71	0,90	0,19	0,43	0,48	0,29	0,29	0,29	0,14	0,29
							E5.3	0,24	0,10	0,52	0,90	0,33	0,05	0,29	0,71	0,81	0,24	0,43	0,43	0,29	0,19	0,19	0,05	0,19
							E5.4	0,10	0,05	0,52	0,71	0,19	0,10	0,19	0,52	0,81	0,19	0,48	0,57	0,38	0,33	0,33	0,19	0,24
							E5.5	0,05	0,05	0,48	0,71	0,24	0,05	0,19	0,52	0,81	0,14	0,29	0,38	0,29	0,24	0,29	0,05	0,00
						E6	E6.1.	0,00	0,00	0,38	0,10	0,05	0,24	0,24	0,19	1,00	0,14	0,24	0,43	0,24	0,14	0,19	0,00	0,00
							E6.2.	0,00	0,00	0,38	0,05	0,05	0,24	0,24	0,19	1,00	0,14	0,24	0,48	0,24	0,05	0,10	0,00	0,00
							E6.3.	0,00	0,00	0,38	0,05	0,05	0,24	0,33	0,19	0,90	0,14	0,29	0,43	0,10	0,00	0,05	0,00	0,00
							E6.4.	0,10	0,10	0,48	0,10	0,10	0,29	0,33	0,29	0,90	0,14	0,29	0,43	0,19	0,14	0,19	0,00	0,00
							E6.5.	0,00	0,00	0,38	0,10	0,05	0,05	0,14	0,29	0,71	0,05	0,14	0,29	0,05	0,00	0,05	0,00	0,00
							E6.6.	0,00	0,00	0,29	0,10	0,05	0,05	0,14	0,29	0,71	0,05	0,10	0,29	0,05	0,00	0,00	0,00	0,00
						E7	E7.1.	0,05	0,10	0,10	0,05	0,00	0,19	0,24	0,19	0,71	0,05	0,29	0,52	0,05	0,00	0,05	0,00	0,19
							E7.2.	0,10	0,10	0,19	0,14	0,00	0,14	0,24	0,38	0,81	0,00	0,14	0,48	0,05	0,05	0,05	0,00	0,05
							E7.3.	0,14	0,19	0,48	0,24	0,05	0,19	0,38	0,57	1,00	0,10	0,57	0,62	0,24	0,19	0,24	0,14	0,33
							E7.4.	0,14	0,19	0,33	0,29	0,05	0,24	0,43	0,48	1,00	0,05	0,48	0,57	0,14	0,14	0,19	0,14	0,29
							E7.5.	0,14	0,14	0,48	0,38	0,10	0,24	0,38	0,52	1,00	0,05	0,48	0,57	0,33	0,19	0,19	0,14	0,38
							E7.6.	0,10	0,10	0,38	0,24	0,05	0,19	0,33	0,43	0,81	0,05	0,38	0,52	0,24	0,19	0,19	0,05	0,29
							E7.7.	0,48	0,52	0,43	0,38	0,14	0,29	0,52	0,43	0,90	0,24	0,71	0,52	0,24	0,29	0,19	0,33	0,57
						E8	E8.1.	0,14	0,48	0,52	0,14	0,19	0,14	0,19	0,33	0,81	0,00	0,38	0,33	0,29	0,33	0,29	0,14	0,14
							E8.2.	0,14	0,38	0,52	0,24	0,29	0,24	0,29	0,33	0,81	0,00	0,38	0,33	0,29	0,33	0,29	0,14	0,14
							E8.3.	0,19	0,43	0,62	0,24	0,10	0,10	0,14	0,33	0,76	-0,1	0,43	0,24	0,24	0,24	0,24	0,05	0,05
						E9	E9.1.	0,10	0,10	0,43	0,24	0,05	0,24	0,19	0,29	0,62	0,05	0,62	0,38	0,05	0,05	0,05	0,33	0,33
							E9.2.	0,10	0,10	0,43	0,19	0,05	0,29	0,24	0,29	0,62	0,05	0,62	0,43	0,19	0,14	0,14	0,33	0,33

Appendix 2 template for task 2.1,2.2 and 2.3

Template for the ILO formulation

Reference Program	*Mechanical engineering, Industrial Engineering, Management Engineering*
Reference course/s	*Integrated Manufacturing Systems, Automation of Machining Processes*
Current ILO* /content	
Description of proposed modification /addition	
New content	**Reference Technology/ies:** **Reference Sustainability goal/s:**
Tentative new ILO	
Tentative new TLA**	*What Kind of activities would be good to enable a proper learning process for the related ILO*
Tentative AT***	*what kind of exam or other form of verification of knowledge would suit the assessment of the proposed ILO*
Other	

* Intended Learning Outcome

** Teaching and Learning Activities

*** Assessment Task

References

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