MAESTRO

Manufacturing Education for a Sustainable fourth Industrial Revolution

Project No 2019-1-SE01-KA203-060572

Output 4

Validation and improvement of the proposed courses

2019-2022

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Project Partners

Summary

Funded by the European Union

Document heading

Project title:	**Manufacturing Education for a Sustainable fourth Industrial Revolution**
Output number:	**O4**
Leading organization:	**Politecnico di Torino**
Output title:	**Validation and improvement of the proposed courses**
Schedule:	**From 01-04-2021 to 31-07-2022**
Authors:	**Politecnico di Torino with input from the entire consortium**

Intellectual Output 4 as seen in the proposal:

Output Description

This activity will be an important and unique learning moment for the consortium as a whole. All the learning outcomes proposed in O3 will be integrated in different forms in the normal engineering programs at different HEI for ming the consortium.

This will be, to the Meastro consortium knowledge, the very first set of pilot courses run including the whole spectrum of technologies coming out of the fourth industrial revolution and with specific focus on the sustainability dimension.

The knowledge produced in this activity will be fundamental to enhance the final output of the project and allow fruitful cooperation after it. In order to increase the communication and mutual understanding of respective expertise a specific training activity (see C2) will be run after a consortium meeting in Pisa in June 2021.

Division of work

POLITO will coordinate the activity that will include all the partners in relation to their specific technical expertise.

Organization of activities

T4.1

In this activity the proposed educational units will be run through different pilot courses at selected institution in the Maestro consortium. Feedback from teaching staff and learners will be collected in the form of course evaluation and aptly designed roundtable discussion involving all the stakeholders of the process. This activity will include also the C2 workshop as further way of testing the proposed learning blocks.

T4.2

Feedback analysis and improvement. The results of T4.1 will be the input of an improvement process aimed at aligning the stakeholders' expectation with the actual course embodiment. For each educational unit a new set of ILO, TLA and AT will be proposed.

T4.3

Final course design. The final course design will be produced and documented. All the course information and related material will be made available for the consortium.

C2

Activity Title: Workshop on Maestro educational units

Activity Description: This workshop is aimed at presenting the course material developed at each institution during the project. The teaching staff of each partner will be both presenting the educational units developed and following other partner´s presentation. This is an important moment to explicit the teaching portfolio of

each partner in order to evaluate possible redundancies and synergies and implement effective educational cooperation in the last phase of the project ahead.

Intellectual Output 4 implementation

The activity in the Intellectual Output 4 (O4) was delayed as a consequence of the cascading delays of preceding outputs, due to Covid-19 pandemic. Because of these delays, the whole project was extended after the initial deadline. The new deadline of 31/12/2022 was approved by NA in 25/04/2022. The final end date for the O4 shifted from 31/12/2021 to 31/08/2022. This extension allowed to include in the project all of the pilot courses given in the academic year 2021/2022. The courses of that year were delivered almost normally, without being significantly affected by the limitations due to COVID. Thanks to this additional time it was possible to complete all the activities planned for the O4 without any change or missing outcome.

In detail:

- The educational units proposed in O3 were run through the pilot courses selected in O3 with some additional pilot courses that were added in the second semester of the year.
- A survey was proposed to all the students as a way to collect feedback for the analysis and the improvement of the courses. The answers were collected in the months following the end of the lessons until the deadline of O4.
- The results of the survey and the proposal for improvement were presented at the Transnational Meeting held 1-2 September 2022 in Rzészow.
- The planned LTT, Learning Teaching and Training, (C2) on the presentation of Maestro educational units was executed in presence on 18-24 September 2022. From the original location, Torino (Italy) it was moved to Palermo (Italy) to allow synergy with dissemination activities in the form of the organization of a special session at the HELMETO congress held in Palermo.

Intellectual Output 4 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
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

Results of Intellectual Output 4

The Intellectual Output 4 goal was to implement through pilot courses 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.

#	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

In the following, the proposed learning outcomes are presented according to O3. Then the pilot courses that were selected to implement the educational units. The survey developed to collect feedback from students is presented and discussed. The results of students' answers are analyzed with extensive comparisons among different courses, different countries and different enabling technologies. The analysis allowed the improvement of the educational units as reported in the following.

Proposed 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

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

- Context where the action for the related content must be applied

KTH –Sweden

Proposal 1 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

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

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 economical and environmental impact of new digital technologies in the current operations framework of a real case study along with proposed solutions as well as implementation strategies.	Evaluate	Economical and environmental impact of new digital technology	Industrial case study Manufacturing

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

Summary of the pilot courses and their implementation during the academic year 21/22

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		

The implementation and the outcomes of the survey are reported in the following table

Institution	Name of the educational unit	I4.0 Tech	Done	Survey answered	Number of answers*
KTH	Planning and Control course – Lean lab exercise	AR	Y	Y	>20
PRZ	Lean Manufacturing I MP-DU	IoT	Y	Y	>10
	Lean Manufacturing II MP-ZU	IoT	Y	Y	
	Decision Support Systems	BDA	Y	Y	>10
POLITO	Sustainable Additive Manufacturing	AM	Y	Y	>60
UNIPI	AM in medical implants	AM	Y	Y	>20

*As the survey was proposed online using Google Forms, new answers are continuously adding to the total.

Definition of the expected outcomes from the survey

A questionnaire was produced to assess the impact, either positive or negative, of I4.0 on SDGs through didactic modules designed by Constructive Alignment.

The questionnaire was subject of long discussions within the consortium and at the end was completely revised and modificated.

There was a serious risk that the questionnaire was seen as an assessment of the quality of teaching and not as an assessment of the course design. In a nutshell, students could be tempted to judge the teacher. Obviously, every University already give questionnaires on teaching quality to have a feedback on the quality of teaching. This questionnaire has another goal, therefore the following disclaimer was added at the beginning of the questions list:

"Disclaimer: this is a finding survey on how much it could be possible to communicate the impact of I4.0 on SDGs through proposing new Teaching and Learning Activities. This is not a replicate questionnaire on the quality of teaching. The survey is not related to a performance rating at any mean and is solely for research and development purposes."

A most subtle risk of failure in acquiring student feedback was in the confirmation bias implied in every questionnaire on environmental themes. We realized that most questions were biased because of emerging environmental sensibility. Putting the questions in term of agree or disagree was misleading. Everyone likes environment and thinks that human action, by extension human technology, be detrimental for the environment. The questionnaire risked to be biased and out of scope. The students could be tempted to agree with every question mentioning the sustainability.

The aim of the questionnaire is to find if the project was able to explicit the impact (positive or negative) of I4.0 enabling technologies on SDGs through didactic modules designed by Constructive Alignment. The aim is not to ask if technology is good for the environment or not.

Therefore, we changed the answers to questions from the former (agree, …, disagree) to an unsigned range (not at all, …, a lot). The students were no more biased by implied confirmation or dissent towards technology and environment. We had to change the wording of the questions accordingly.

A side outcome of the questionnaire was to see if there was a correlation among the results and the following factors: the country where the course was given, the University, the specific technology addressed by the didactic module, the gender of students. Gender was included as a factor because everywhere in Europe engineering courses are attended by a predominantly male student population. The following factors were neglected: nationality of students, age of the students. The reason is that the data collected were not numerous enough to allow a statistic analysis of the influence of student nationality or age on the answers.

The questionnaire was completed with a set of open questions with the aim of collecting students' proposals for the improvement of Intended Learning Outcomes, and of the Teaching and Learning materials. In this way it became the survey that is reported in the next section.

Description of the survey submitted to students

General section

- Gender
- Age
- Nationality
- University (select from list)
- Course (select from list)
- I4.0 Technology involved (select one or more from the list)

Compulsory section

Dimension	Question
GENDER	Please select your gender:
COUNTRY EFFORT	In your opinion, to what extent is Italy / Poland / Sweden doing practical steps towards sustainability?
UNIVERSITY ATTENTION	Please rate the consideration of Sustainability in your University program:
ADDITIONAL KNOWLEDGE	Please select to what extent the I4.0 enabling technology presented in the course complement your base of knowledge in the field:
FUTURE WORK QUALITY	In your opinion, to what extent the knowledge about this I4.0 enabling technology will improve the quality of your future work?
IMPACT ON SUSTAINABILITY	In your opinion, please select to what extent overall this I4.0 technology affects sustainability:
INDUSTRY SDG 9 (PROCESS)	In your opinion, to what extent this I4.0 enabling technology improves the industrial process it is applied to?
Please rate the impact of this I4.0 technology on each of the following sustainability goals (SDG 9 has a specific question as the most relevant SDG):	POVERTY (SDG 1) FOOD (SDG 2) HEALTH (SDG 3) EDUCATION (SDG 4) WATER (SDG 6) ENERGY (SDG 7) GROWTH (SDG 8) PRODUCTION & CONSUMPTION (SDG 12) CLIMATE (SDG 13)

There are 4 levels on answer:

0--> Not at all/No Impact/None

1 --> Slightly/Low Impact/Low

2--> Moderately/Moderate Impact/Moderate

3--> Extremely/High Impact/High

Voluntary section - Open questions

1. Think about what you have learnt through the course; How I4.0 enabling technologies helped to improve the solution to production problems compared with traditional approach?
2. What are the advantages of considering sustainability issues in the presentation of I4.0?
3. What were the difficulties or drawbacks that you encountered during the project implementation?
4. Are there any suggested changes to the way the teaching and learning material is structured?
5. What are your suggestions to increase the sustainability consideration during the application of I4.0?

Analysis of the answers to the survey

The aggregated answers are equally distributed for genre: 63 females and 68 males.

Here is the detailed distribution of respondents by University

University	Male	Female
POLITO	31	31
UNIPI	11	11
KTH	15	6
PRZ (IOT)	7	7
PRZ (BDA)	4	8

The survey was tested for consistency using the Cronbach test. The interpretation of the test is in the following table

Cronbach's alpha	Internal consistency
α >= 0.9	**Excellent**
0.8 <= α < 0.9	**Good**
0.7 <= α < 0.8	**Acceptable**
0.6 <= α < 0.7	Questionable
0.5 <= α < 0.6	Poor
α < 0.5	Unacceptable

Cronbach test

University	Cronbach's alpha	Internal consistency
POLITO	0.81	Good
UNIPI	0.82	Good
KTH	0.9	Excellent
PRZ (IOT)	0.92	Excellent
PRZ (BDA)	0.79	Acceptable

Aggregate answers to the compulsory section of the questionnaire

COUNTRY EFFORT

Mean: 1.576 Std Dev: 0.722

Value	0	1	2	3
Frequency	6	56	58	12
Proportion	0.045	0.424	0.439	0.091

UNIVERSITY ATTENTION

Mean: 1.924 Std Dev: 0.672

Value	0	1	2	3
Frequency	1	32	75	24
Proportion	0.008	0.242	0.568	0.182

ADDITIONAL KNOWLEDGE

Mean: 2.136 Std Dev: 0.707

Value	0	1	2	3
Frequency	2	19	70	41
Proportion	0.015	0.144	0.530	0.311

FUTURE WORK QUALITY

Mean: 2.258 Std Dev: 0.758

Value	0	1	2	3
Frequency	3	16	57	56
Proportion	0.023	0.121	0.432	0.424

IMPACT ON SUSTAINABILITY

Mean: 2.197 Std Dev: 0.725

Value	0	1	2	3
Frequency	3	15	67	47
Proportion	0.023	0.114	0.508	0.356

Impact on SDGs

POVERTY – SDG 1

Mean: 1.47 Std Dev: 0.886

Value	0	1	2	3
Frequency	18	51	46	17
Proportion	0.136	0.386	0.348	0.129

FOOD – SDG 2

Mean: 1.439 Std Dev: 0.910

Value	0	1	2	3
Frequency	22	46	48	16
Proportion	0.167	0.348	0.364	0.121

HEALTH – SDG 3

Mean: 2.045 Std Dev: 0.799

Value	0	1	2	3
Frequency	6	21	66	39
Proportion	0.045	0.159	0.500	0.295

EDUCATION – SDG 4

Mean: 2.008 Std Dev: 0.969

Value	0	1	2	3
Frequency	13	22	48	49
Proportion	0.098	0.167	0.364	0.371

WATER – SDG 6

Mean: 1.909 Std Dev: 0.851

Value	0	1	2	3
Frequency	7	33	57	35
Proportion	0.053	0.250	0.432	0.265

ENERGY – SDG 7

Mean: 2.288 Std Dev: 0.851

Value	0	1	2	3
Frequency	5	19	41	67

GROWTH – SDG 8

Mean: 2.205 Std Dev: 0.759

Value	0	1	2	3
Frequency	3	18	60	51
Proportion	0.023	0.136	0.455	0.386

INDUSTRY – SDG 9

Mean: 2.303 Std Dev: 0.676

Value	0	1	2	3
Frequency	2	10	66	54
Proportion	0.015	0.076	0.500	0.409

PRODUCTION & CONSUMPTION – SDG 12

Mean: 2.311 Std Dev: 0.753

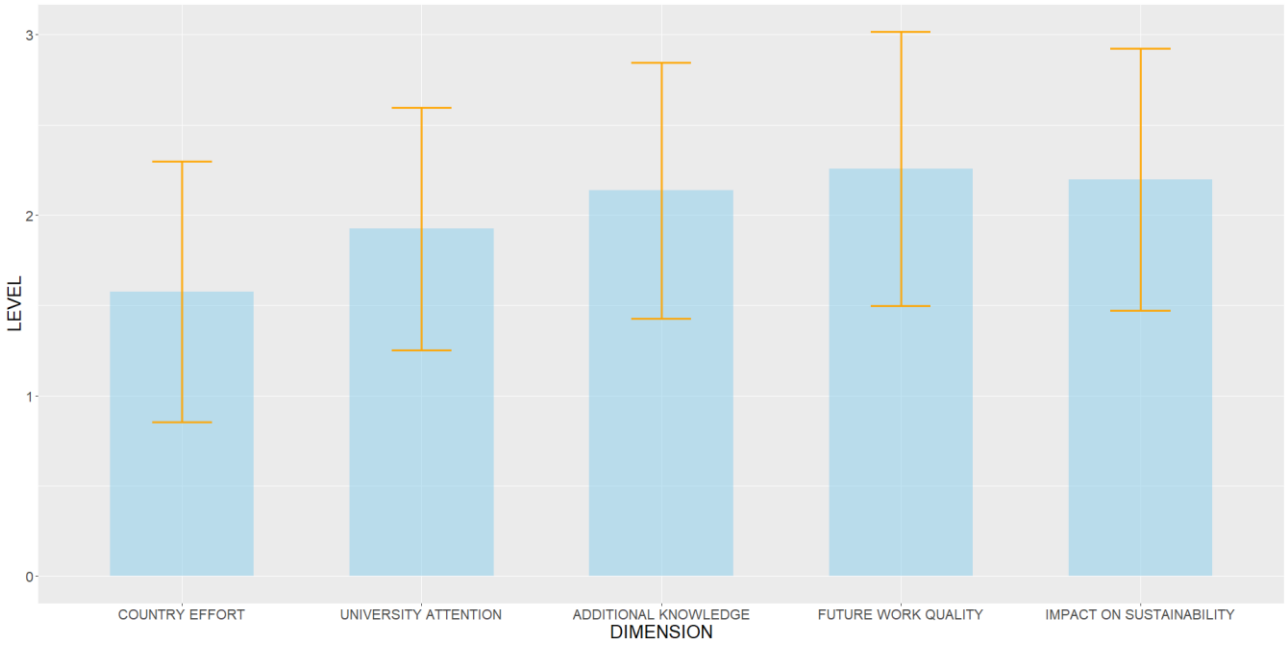
Value	0	1	2	3
Frequency	4	11	57	60
Proportion	0.030	0.083	0.432	0.455

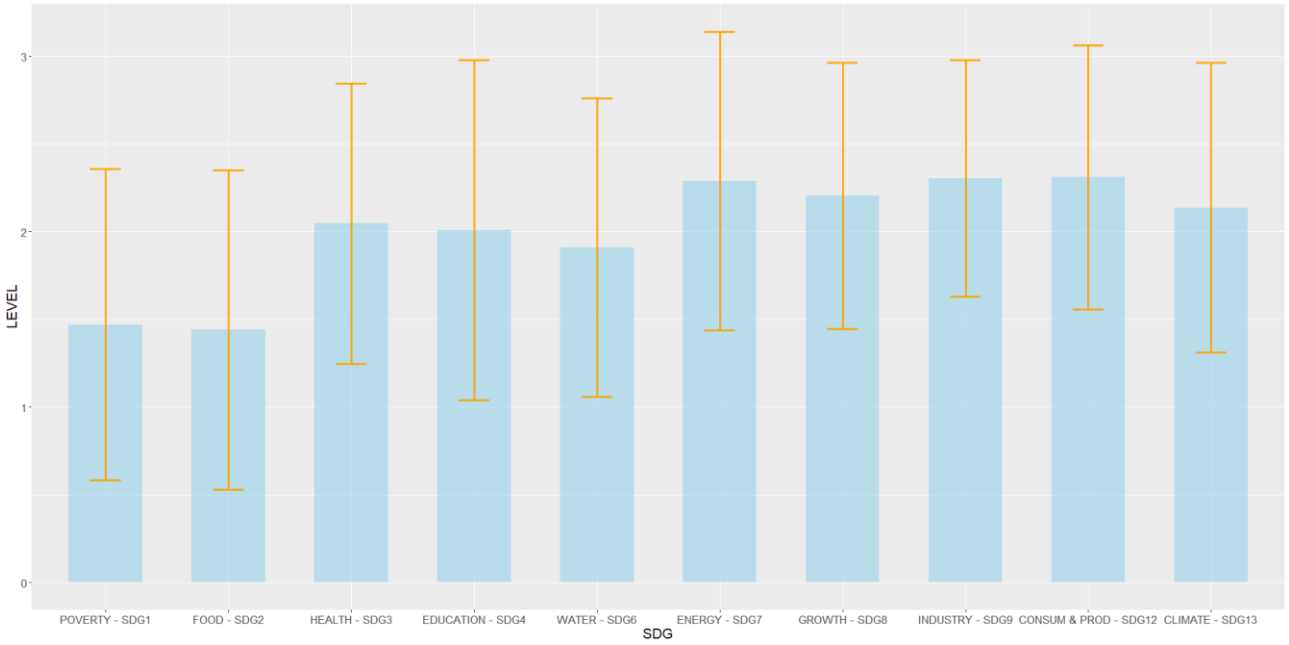
CLIMATE – SDG 13

Mean: 2.136 Std Dev: 0.827

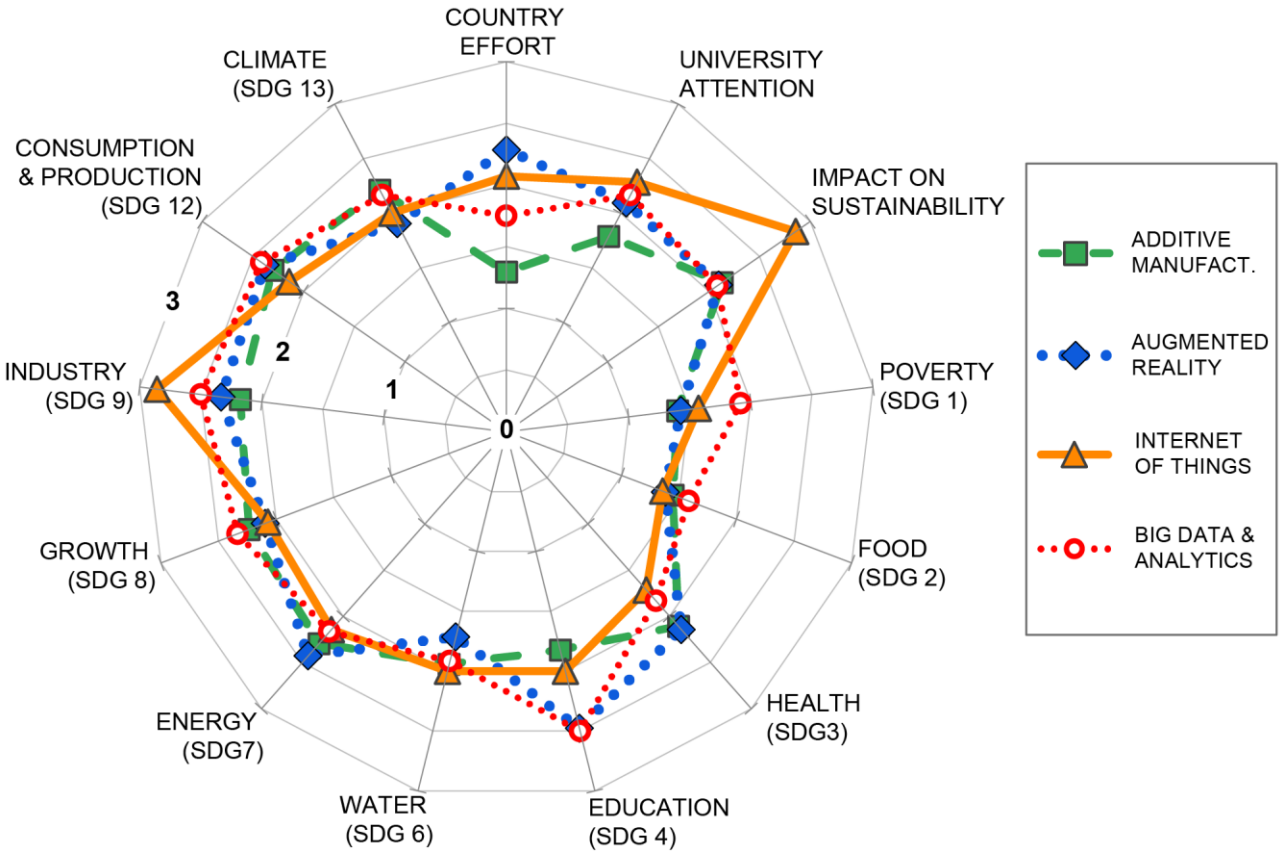
Value	0	1	2	3
Frequency	5	22	55	50
Proportion	0.038	0.167	0.417	0.379

The overall answers are here represented on a bar chart for sake of concision.





An alternative and valuable representation of survey results is the radar plot with the scores split by the enabling technology object of the course.



Statistical Tests

The Krusk-Wallis one-way ANOVA by ranks can be used for testing whether, within each aspect, responses from students from different Universities/Courses originate from the same distribution. It is used for comparing more than two groups that are independent and have different sample sizes.
The H0 of the Krusk-Wallis test is that the medians of all groups are equal, and the alternative hypothesis is that at least one population median of one group is different from the population median of at least one other group.

Dimension	Test result
COUNTRY EFFORT	**< 0.001 ****
UNIVERSITY ATTENTION	**0.002 ****
ADDITIONAL KNOWLEDGE	**< 0.001 ****
FUTURE WORK QUALITY	0.353
IMPACT ON SUSTAINABILITY	**0.001 ****

The values with ** are significant and pass the H0 K-W test.

SDG	Test result
POVERTY (SDG1)	0.332
FOOD (SDG2)	0.892
HEALTH (SDG3)	0.340
EDUCATION (SDG4)	**0.012 ****
WATER (SDG6)	0.629
ENERGY (SDG7)	0.707
GROWTH (SDG8)	0.619
INDUSTRY (SDG9)	**0.001 ****
PROD & CONSUMP (SDG12)	0.931
CLIMATE (SDG13)	0.419

The inference is that the medians differ, but to know to which pair(s) we can attribute this to, the post-hoc Dunn test should be carried out.

Post-hoc Dunn test results

Dimension	KTH vs POLITO+UNIPI	PRZ vs POLITO+UNIPI	PRZ vs KTH
COUNTRY EFFORT	< 0.001 **	< 0.001 **	0.153

Dimension	UNIPI vs POLITO	KTH vs POLITO	PRZ vs POLITO	KTH vs UNIPI	PRZ vs UNIPI	PRZ vs KTH
University attention	0.110	0.418	0.100	0.030 **	0.002 **	0.465
IMPACT ON SUSTAINABILITY	1.00	< 0.001 **	1.00	0.005 **	1.00	0.001 **
EDUCATION (SDG4)	0.033 **	0.902	0.145	0.902	0.992	0.902
INDUSTRY (SDG9)	0.690	0.001 **	0.383	0.066	0.690	0.440

** Significant for $\alpha = 0.05$ (Reject H0 if $p <= \alpha/2$)

Answers to the voluntary section of the questionnaire

The suggestions and the remarks of the students have been collected and were used to improve the final design of the educational units. In the following just a sample of received answers is provided for sake of concision. The complete list of answer is available for consultation on the project MAESTRO website.

POLITO

- More practical applications
- Extend sustainability attention to all the other courses
- Study other ways of conceiving the industrial production than just study improvements of the current economic system
- More practical and physical examples of the processes (videos, experiments or a visit to a manufacturing plant)
- Using some simulators for some applications could be interesting

UNIPI

- Even if it is easy and fast to produce through AM, it's still important to test through computer software the results before 3d printing
- Look for bio-sustainable materials
- Focus on the materials used and also ensure that there is a valid justification among the production with that specific technology and that specific material.
- In one student's opinion the strength of Additive Manufacturing is on the prototyping side

KTH

- work more for less, talk about it more, give it more time during the start of the course

PRZ

- Standardization of cross universities learning program to achieve common plane for communication.
- Introduce the possibility of additional work in the online system after lessons

Links to survey files on project's website

Questions for student feedback

Results of student feedback

Analysis of Student Feedback

Funded by the European Union

Educational unit final design after the analysis of Survey outcomes

KTH

ILO1: __ Explain and use suitable VR and AR implementations for assembly on a lean shop floor.___

SDGs	Target	Positive impact	Negative impact
SDG 4 – Quality Education	4.4	Teaching AR and VR will increase number of youth and adults who have relevant and currently needed technical skills in industry. This will enhance employment, decent jobs and entrepreneurship.	
SDG 8 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.2	Capabilities in VR and AR technology may enhance the ability and productivity of workers. This is achieved through diversification, technological upgrading, and innovation.	
	8.8	AR and VR promote safe and secure working environment for all workers.	
SDG 9 – Industry, innovation and infrastructure	9.5	Capabilities in AR and VR contribute to an upgrade of the existing technological capabilities of industrial sectors in all countries, encouraging innovation.	

POLITO

ILO1: Evaluate the environmental performance of different manufacturing approaches by modelling their sustainability through Life-Cycle Assessment and other state-of-the-art methodologies.

SDGs	Target	Positive impact	Negative impact
SDG 12 - Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Target 12.2: Sustainable management and use of natural resources	Design and/or selection of manufacturing processes with an increased awareness on the strict correlation between manufacturing, material consumption and material footprint.	
	Target 12.5: Substantially reduce waste generation	Expected reduction in manufacturing waste generation through prevention, reduction, recycling and reuse, under a circular economy vision.	
	Target 12.6: Encourage companies to adopt sustainable practices and sustainability reporting	Make technicians aware of the methodologies for the environmental performance assessment of manufacturing systems.	
SDG 9 - Industry, innovation and infrastructure	Target 9.4: Upgrade all industries and infrastructures for sustainability	Potential increase in resource-use efficiency and adoption of clean and environmentally sound technologies and industrial processes.	

PRZ: Decision Support Systems

ILO1: 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

SDGs	Target	Positive impact	Negative impact
SDG 3 – Good health and well-being	3.4 – By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	Analysis of time series from patient monitoring can help detect anomalies and better diagnose patients, which can improve prevention.	

SDGs	Target	Positive impact	Negative impact
SDG 7 – Affordable and clean energy	7.1 – By 2030, ensure universal access to affordable, reliable and modern energy services	Analysis of time series from energy consumption monitoring facilitates the implementation of modern energy services, thanks to which the offer of energy suppliers can be better adapted to their customers.	
SDG 8 – Decent work and economic growth	8.8 – Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	Analysis of time series from workplace monitoring can help detect anomalies that threaten worker safety.	
	8.10 – Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all	Analysis of time series that relate to customers of financial institutions (e.g. data on the account balance of a bank's customers) can help better manage risk and offer relevant products to the customers.	
SDG 9 – Industry, innovation and infrastructure	9.4 – By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking	Analysis of time series from industrial process monitoring can help detect abnormalities, which can improve the use of machinery and other means of work.	

SDGs	Target	Positive impact	Negative impact
	action in accordance with their respective capabilities		
SDG 11 – Sustainable cities and communities	11.6 – By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management	Analysis of time series from air quality monitoring can help identify the impact of various factors on air quality.	
SDG 12 – Responsible consumption and production	12.2 - By 2030, achieve the sustainable management and efficient use of natural resources	Analysis of time series from the monitoring of resource consumption (e.g. water) makes it easier to detect anomalies (e.g. leakages caused by an installation failure), which can contribute to a more efficient use of natural resources.	

Funded by the European Union

PRZ: Lean Manufacturing

ILO1: Develop a value stream map taking into account economic, social and environmental aspects.

SDGs	Target	Positive impact	Negative impact
SDG 3 - Good Health and Well-being (How the work environment can be improved?)	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Thanks to the development of a sustainable value stream map, it will be possible to identify processes in which hazardous substances are used or which have a negative impact on the environment. On this basis, it will be possible to take actions to minimize the negative impact on the environment.	
SDG 6 - Clean Water and Sanitation (How the influence on water consumption and clean can be monitored?)	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Thanks to the development of a sustainable value stream map, it will be possible to identify processes that may lead to water pollution. On this basis, it will be possible to take measures to minimize the negative impact on water pollution.	

SDGs	Target	Positive impact	Negative impact
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Thanks to the development of a sustainable value stream map, it will be possible to identify the processes in which water is used. On this basis, it will be possible to take measures to minimize the amount of water used.	
SDG 8 - Decent Work and Economic Growth (How the decent work and a company development can be achieved?)	8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	Thanks to the development of a sustainable value stream map, it will be possible to identify processes in which there are threats to the health and life of employees. On this basis, it will be possible to take measures to minimize the level of occupational risk.	
SDG 13 - Climate Action (How the influence on the climate can be monitored?)	13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Thanks to the development of a sustainable value stream map, the awareness of future industry employees regarding the impact of production processes on the natural environment, and thus climate change, will be raised.	

ILO2: Analyse a current state value stream map taking into account economic, social and environmental aspects.

SDGs	Target	Positive impact	Negative impact
SDG 3 - Good Health and Well-being (How the work environment can be improved?)	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	Thanks to the analysis of the current state of the sustainable value stream map, it is possible to identify activities that minimize the use of hazardous substances and thus the negative impact on the environment.	
SDG 6 - Clean Water and Sanitation (How the influence on water consumption and clean can be monitored?)	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	Thanks to the analysis of the current state of the sustainable value stream map, it is possible to identify activities that minimize the negative impact on water pollution.	
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	Thanks to the analysis of the current state of the sustainable value stream map, it is possible to identify activities that minimize the amount of water used.	

SDGs	Target	Positive impact	Negative impact
SDG 8 - Decent Work and Economic Growth (How the decent work and a company development can be achieved?)	8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	Thanks to the analysis of the current state of the sustainable value stream map, it will be possible to identify processes in which there are threats to the health and life of employees. On this basis, it will be possible to take measures to minimize the level of occupational risk.	
SDG 13 - Climate Action (How the influence on the climate can be monitored?)	13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Thanks to the analysis of the current state of the sustainable value stream map, the awareness of future industry employees regarding the impact of production processes on the natural environment, and thus climate change, will be raised.	

ILO3: Create a future state of the value stream map taking into account IoT solutions.

SDGs	Target	Positive impact	Negative impact
SDG 3 - Good Health and Well-being (How the work environment can be improved?)	3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination	By developing a future state of a sustainable value stream map, it will be possible to show possible changes in processes using hazardous substances that can have a positive impact on the environment.	
SDG 6 - Clean Water and Sanitation (How the influence on water consumption and clean can be monitored?)	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	By developing the future state of the sustainable value stream map, it will be possible to show possible changes in processes that can lead to the reduction or elimination of water pollution.	
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	By developing a future state of the sustainable value stream map, it will be possible to show possible changes in processes that can lead to a reduction in process water consumption.	

SDGs	Target	Positive impact	Negative impact
SDG 8 - Decent Work and Economic Growth (How the decent work and a company development can be achieved?)	8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	By developing a future state of the sustainable value stream map which includes IoT solutions, it will be possible to achieve higher levels of productivity of the implemented processes.	
	8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-Year Framework of Programmes on Sustainable Consumption and Production, with developed countries taking the lead	By developing a future state of the sustainable value stream map which includes IoT solutions, it will be possible to achieve higher levels of resource efficiency in production.	
	8.8 Protect labour rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment	By developing a future state of the sustainable value stream map, it will be possible to achieve a lower level of occupational risk.	

SDGs	Target	Positive impact	Negative impact
SDG 9 - Industry, Innovation and Infrastructure (How the innovations in infrastructure can strengthen the industry?)	9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities	By developing a future state of the sustainable value stream map which includes IoT solutions, it will be possible to increase the sustainability of production.	
SDG 13 - Climate Action (How the influence on the climate can be monitored?)	13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	By developing a future state of the sustainable value stream map which includes IoT solutions, the awareness of future industry employees regarding the impact of IoT solutions on production processes, the natural environment, and thus climate change, will be raised.	

UNIPI

ILO1: Compare and select among classical polymers, metals and ceramics as well as innovative biodegradable materials in the context of additive manufactured medical prosthesis by minimising the environmental impact

ILO2: Design and optimise the environmental impact of AM processes for single medical devices production

SDGs	Target	Positive impact	Negative impact
SDG3	3.8	AM enable quality, affordable and universal machines and methodologies for producing medical implants even in remote locations	
SDG9	9.3	AM increases the access of new markets of small-scale industrial and other enterprises, in particular in developing countries.	
	9.5	Capabilities in AM contribute to an upgrade of the existing technological capabilities of industrial sectors in all countries, encouraging innovation.	
SDG12	12.5	AM substantially reduce waste generation through a better use of material and parameters optimization	

Tematic Calendar and links to the TL material available on the project website

KTH

ILO1: __ Explain and use suitable VR and AR implementations for assembly on a lean shop floor

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description	Responsible
w1	weekday	Date	Begin time	End time	TLA	Lecture	Room number	Title: AR and VR Content: Present AR and VR technology in a lean manufacturing context. Explain how AR and VR technology can be applied for assembly instructions.	Teacher
w2	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab	Title: AR and VR demonstration Content: Demonstration of a real application of AR and VR for assembly instructions in the assembly line used for the lab session. The students in group actively participate to the demonstration using the application.	Teacher assistant
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
w4	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab	Title: AR and VR demonstration Content: Demonstration of a real application of AR and VR for assembly instructions in the assembly line used for the lab session. The students in group actively participate to the demonstration using the application.	Teacher assistant
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
w5**	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab	Title: AR and VR demonstration Content: Demonstration of a real application of AR and VR for assembly instructions in the assembly line used for the lab session. The students in group actively participate to the demonstration using the application.	Teacher assistant
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
	weekday	Date	Begin time	End time	TLA + AT	Lab session*	Lab		
w6	weekday	Date	Begin time	End time	AT	Exam	Room number	Fianl exam (essay questions)	Teacher

Week	Link to TL material
W1	https://overlyapp.com/augmented-reality-solutions/education-training/ https://drive.google.com/file/d/1BodSTaKYgA7WA4lMQ0yQd9KYvbpUqc-S/view?usp=sharing https://docs.google.com/presentation/d/1-9vF12imKNxVES8i5OoPSNbCb3ucTSFG/edit?usp=sharing&ouid=104669036118705406974&rtpof=true&sd=true
W2	https://play.google.com/store/apps/details?id=com.Overly.Cloud&hl=en&gl=US
W4	https://play.google.com/store/apps/details?id=com.Overly.Cloud&hl=en&gl=US
W5	https://play.google.com/store/apps/details?id=com.Overly.Cloud&hl=en&gl=US
W6	-

POLITO

ILO1: Evaluate the environmental performance of different manufacturing approaches by modelling their sustainability through Life-Cycle Assessment and other state-of-the-art methodologies.

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description	Responsible
w1	weekday	Date	Begin time	End time	TLA	Lecture	Classroom	Introduction to the state-of-the-art methodologies for comparing the environmental impact of manufacturing processes	Teacher
	weekday	Date	Begin time	End time	TLA	Lecture	Classroom		
w2	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom	Implementation of the methodologies, development of decision-support tools for process comparison/selection	Teacher / Teacher assistant
	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom		
	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom		
w3	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom	Implementation of the methodologies, development of decision-support tools for process comparison/selection, discussion of the results	Teacher / Teacher assistant
	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom		
	weekday	Date	Begin time	End time	TLA + AT	Classwork	Classroom		

Week	Link to TL material
W1	Comparison example
W2	Explicative journal paper
W3	-

UNIPI

ILO1: Compare and select among classical polymers, metals and ceramics as well as innovative biodegradable materials in the context of additive manufactured medical

ILO2: Design and optimize the environmental impact of AM processes for single medical devices production

Week	Weekday	Date	Time slot		Location	TLA/AT	Type of activity	Description	Responsible
w1	weekday	Date	Begin time	End time	Room number	TLA	Lecture/Lab	Title: CAD modeling basis and 3D software Content: Introduction to industrial technical drawing. Use of Autodesk CAD Fusion 360 (i.e., introduction to the software, and related exercises). Explain the main theoretical basis concerning AM and CAD modeling. Total 2+(2exercitations for the project) hours	Teacher and assistant
	weekday	Date	Begin time	End time	Room number	TLA	Lecture/Lab		
	weekday	Date	Begin time	End time	Room number	TLA	Lecture/Lab		
	weekday	Date	Begin time	End time	Room number	TLA	Lecture/Lab		
w2	weekday	Date	Begin time	End time	Room number	TLA	Lecture	Title: AM process, basis, workflow and materials Content: Introduce manufacturing technologies. Provide examples of AM processes parameters and material selection in medical sectors, environmental impact of the production processes as well overall impact on SDGs. Total 2+(2exercitations for the project) hours	Teacher
	weekday	Date	Begin time	End time	Room number	TLA	Lecture		
	weekday	Date	Begin time	End time	Room number	TLA	Lecture		

Week	Weekday	Date	Time slot		Location	TLA/AT	Type of activity	Description	Responsible
w3	weekday	Date	Begin time	End time	Room number	TLA	Lecture	Title: Sensing for online control and process optimization Content: Although many efforts have been dedicated by industry and research in the last decades, a significant room for improvements is still present for AM sensing techniques. This short lecture provide an overview on that	Teacher
w4	weekday	Date	Begin time	End time	Room number	TLA	Lecture	Title: Project description, support and review (around 10 hours) Content: Students asks questions and help in developing the specific project	Teacher and assistant
w6	weekday	Date	Begin time	End time	Room number	AT	Exam	Final exam (written test containing theoretical questions, and exercises ii) written project work iii) oral examination on the project work and theoretical concepts)	Teacher

Week	Link to TL material
W1	CAD software for AM: Theory and practice
W2	Laboratory of biomedical technologies-Additive Manufacturing
W3	Sensing for online control and process optimization
W4	-
W6	-

PRZ: Decision Support Systems

ILO1: 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

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description
w1	weekday	Date	Begin time	End time	TLA	Lab session	Classroom	Title: Introduction on time series and machine learning Content: Introduction (presentation) on machine learning techniques and time series; Discussion on the opportunities to apply machine learning in time series analysis; Introduction to the case study and discussion of the analyzed dataset
	weekday	Date	Begin time	End time	TLA	Lab session	Classroom	Title: Hierarchical clustering Content: Introduction to hierarchical clustering; Solving tasks on data import, data preprocessing, outliers finding and clustering of time series using hierarchical techniques; Solving tasks that verify the acquired knowledge of hierarchical clustering of time series.
w2	weekday	Date	Begin time	End time	TLA	Lab session	Classroom	Title: Non-hierarchical clustering Content: Introduction to non-hierarchical clustering and feature extraction from time series; Solving tasks on feature extraction from time series, clustering of time series using non-hierarchical techniques and cluster quality evaluation; Solving tasks that verify the acquired knowledge of non-hierarchical clustering of time series.
w3	weekday	Date	Begin time	End time	AT	Theoretical exam	Classroom	A test on machine learning techniques.
w4	weekday	Date	Begin time	End time	AT	Practical exam	Classroom	Solving tasks related to the clustering of time series

Week	Link to TL material
W1	https://docs.google.com/document/d/1Zp9l1J6jWtJxxxOu7_gbJdi0n9p21xM-/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true https://docs.google.com/document/d/1ffB2B8zIsnTBt_qu_7lG0Hj6ngIOqIkJ/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true
W2	https://docs.google.com/presentation/d/1sw2_gy3BV5pVUCl8052ic3Z36J5IKapa/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true https://docs.google.com/presentation/d/1uPB7ELXC5sBq-kpwA2kwjjrBb7BZCyIo/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true

PRZ: Lean Manufacturing

ILO1: Develop a value stream map taking into account economic, social and environmental aspects.

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description
w1	weekday	Date	Begin time	End time	TLA	Lecture	Classroom	Sustainable value stream mapping – principles of developing of the current state map. Development of a value stream map (current state) based on the provided data.
	weekday	Date	Begin time	End time	TLA	Classwork	Classroom	
w2	weekday	Date	Begin time	End time	TLA / AT	Classwork	Classroom	Sustainable value stream mapping – principles of developing of the current state map.

ILO 2- Analyse a current state value stream map taking into account economic, social and environmental aspects.

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description
w2	weekday	Date	Begin time	End time	TLA / AT	Classwork	Classroom	Analysis of the current state of the value stream map and identification of problems

ILO 3- Create a future state of the value stream map taking into account IoT solutions.

Week	weekday	Date	Time slot		TLA/AT	Type of activity	Location	Description
w3	weekday	Date	Begin time	End time	TLA	Lecture	Classroom	Sustainable value stream mapping – principles of developing of the future state map. Proposals for solutions to problems and development of the future state map.
	weekday	Date	Begin time	End time	TLA / AT	Classwork	Classroom	
w4	weekday	Date	Begin time	End time	TLA	Lecture	Classroom	Sustainable value stream mapping – principles of developing of the future state map. Proposals of IoT technology implementation.
	weekday	Date	Begin time	End time	TLA / AT	Classwork	Classroom	

W1	Sustainable VSM
W2	https://docs.google.com/spreadsheets/d/1FBMJQ17PL4OCdfb3Uk9hw7fzQlED9Dg5/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true https://docs.google.com/document/d/1lPcYI5HmOJw9vKx0drDjCn4s-7bX9gKR/edit?usp=sharing&ouid=115060677425752247725&rtpof=true&sd=true
W3	Sustainable VSM
W4	Sustainable VSM https://irojournals.com/iroismac/article/pdf/4/4/3