



MAufacturing Education for a suSTainable fourth industRIal revOlution



August the 23rd 2022

Stockholm, Sweden

HEIn4.⏻

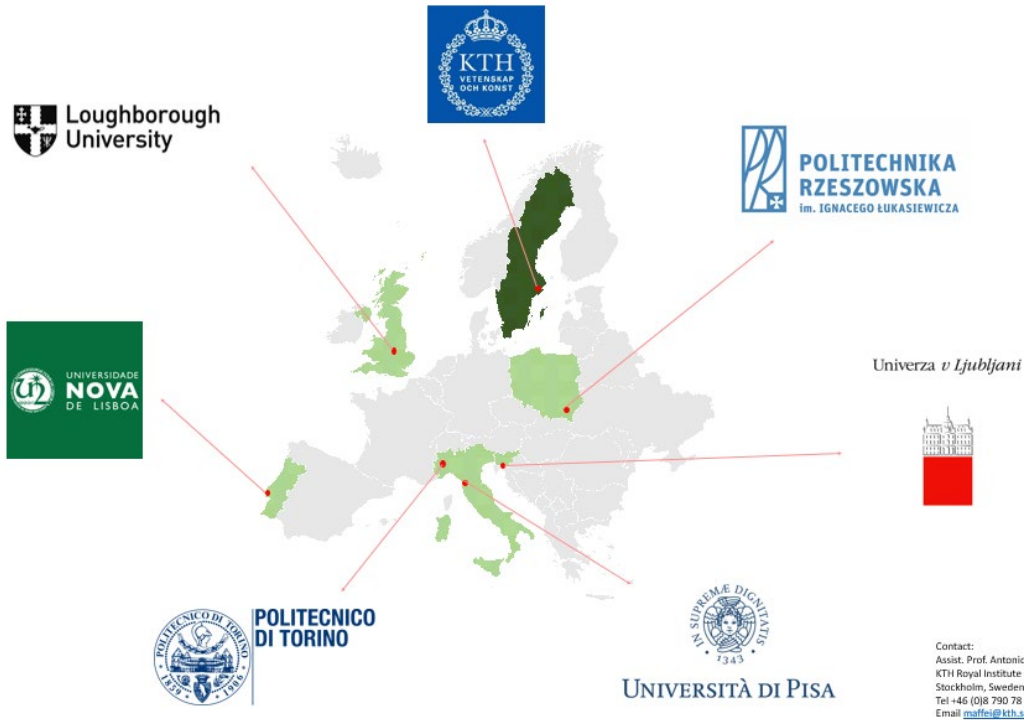


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Partner



Swedish Council for
Higher Education



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XPRES

Initiative for excellence in production research



Description of the project: Objective

The aim of this initiative is to bring together excellences in manufacturing research in order to define and deliver the new competences required by future engineers working in the context of the fourth industrial revolution. In doing so particular emphasis is given to the aspect related with a sustainable transition to the digital era.



Problem

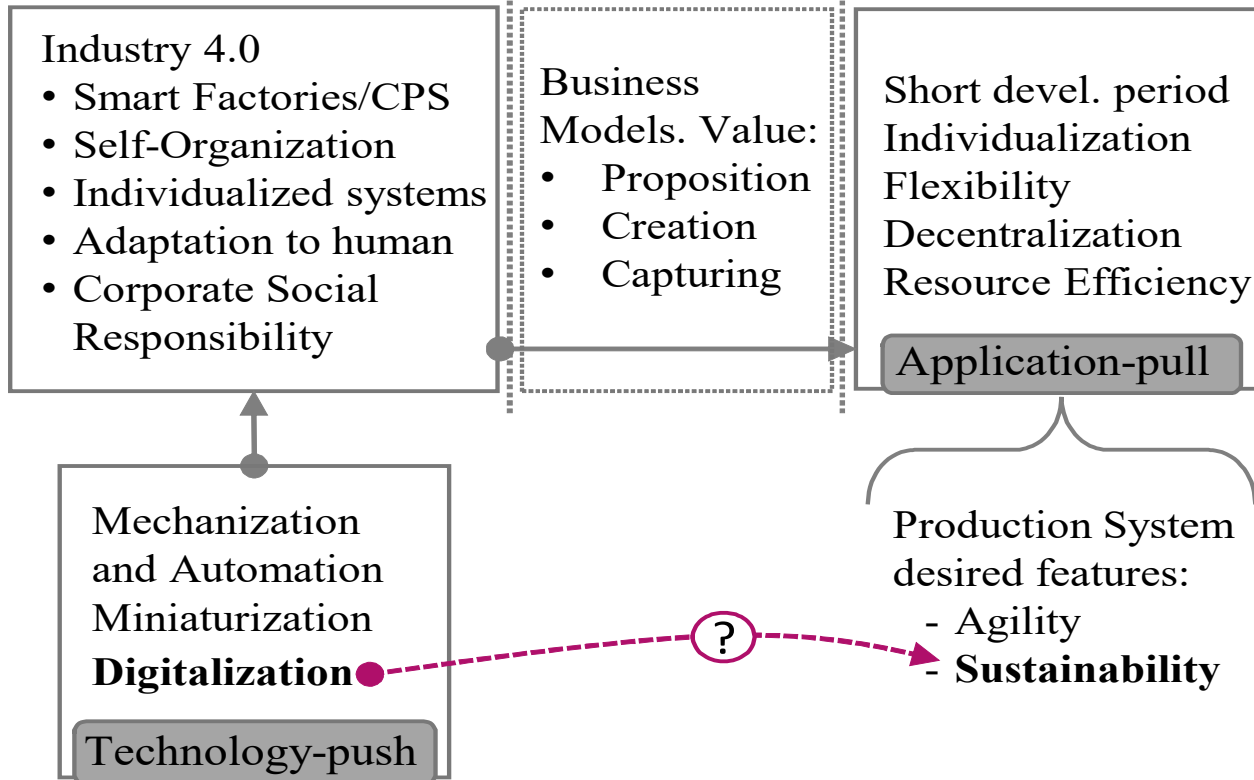
Keywords used for the research

Period	Manufacturing Sustainability	Manufacturing Digitalization	Manufacturing Sustainability Digitalization
	WoS - Scopus	WoS - Scopus	WoS - Scopus
2006-2008	214 - 78	11 - 4	0 - 0
2009-2011	483 - 226	11 - 2	0 - 0
2012-2014	959 - 457	17 - 4	1 - 0
2015-2017	2004 - 776	111 - 31	6 - 1

Digitalization is perceived as new “soil” or ne “oil” rather than a chance to steer development towards sustainability

A way of looking at it

Invention + Application = Innovation





Description of the project: Activities and methodology

4 phases related to the defined intellectual outputs:

1. Identification the academic and industrial contributions that are shaping the fourth industrial revolution. Emphasis on technologies implemented in line with the objectives proposed by the UN Agenda for sustainable development
2. Definition of new engineering profiles including the selected desired skills. This includes the description of specific learning outcome addressing gaps and mismatches identified in the previous phase



Description of the project: Activities and methodology

4 phases related to the defined intellectual outputs:

3. Embodiment of the learning outcome in constructively aligned pilot courses that will be run at the single institution
4. Implementation of the stakeholder feedback on the pilot course, validation and release of the final education units

In addition to this we have a fifth activity:

5. Definition of cooperation beyond the project to exploit the produced contribution: these includes but are not limited to joined profiles, double-degrees, students and teaching exchange.



Description of the project: results and impact

The main outcome of the initiative will be a series of up to date course based on academic and industrial contribution (see O3* and O4*) on the following topics:

- Virtual reality, augmented reality (Pisa University),
- Additive manufacturing (POLITO-PISA),
- Autonomous Robot and Human robot cooperation (POLITO)
- Sustainable Business Models: Shared Economy and Circular Economy (KTH)
- Multi Agent based Control (UNL)
- Machine Learning (Lboro)
- Big data (PRz)
- Block chain and cybersecurity (KTH)

*O3 and O4 stands for Intellectual Output 3 and 4



Redefinition of engineering curricula

Partners leading the update of the targeted engineering profile at the moment of writing the proposal. All the partners will anyway work to some extent in each profile:

- Mechanical engineer (Pisa)
- Industrial engineer (PRz)
- Electrical engineer (UNL)
- Management Engineer (KTH)



Description of the project: results and impact

All the courses will highlight theories and practices supporting the objectives of the **UN Agenda for Sustainable Development**. Other outcomes of the project includes:

- A research diary with the most important contribution and practices in the industry 4.0 domain with focus on sustainability issues (see O1)
- Engineering profile description including relevant and updated skill in the industry 4.0 domain with focus on sustainability issues (see O2)
- Training activities for the partners (see C1* and C2*)
- Multiplier Event (see E1-E2-E3**)
- Long term cooperation and synergies between the involved organizations (O5)

*C1 and C2 stands for the planned Training 1 and 2

** E1-E2-E3 are the three planned multiplier events



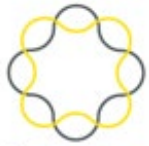
Intellectual Outputs

ID	Output Title	Category of Staff	
O1	Mapping and selection of Industry 4.0 contributions eligible for education	Teachers/Trainers/Researchers	Lboro
O2	Definition of new competences in the domain of Industri 4.0 for different engineering profiles	Teachers/Trainers/Researchers	
O3	Development of constructively aligned courses in the domain of Industry 4.0	Teachers/Trainers/Researchers	KTH
O4	Validation and improvement of the proposed courses	Teachers/Trainers/Researchers	
O5	Exploitation though Synergies in Education	Teachers/Trainers/Researchers	



Output 1

- This activity is the first step in an attempt to systematize the body of knowledge produced in the domain of the fourth industrial revolution with the aim of selecting suitable concepts to be introduced in undergraduate engineering education. Particular attention will be devoted to the contribution that positively impact the UN agenda for Sustainable development objectives.
- The results of the effort will be presented through a public research diary document that presents all the eligible innovative topics as well as the rationale for including them in undergraduate education. This is expected to be a living document that can be freely used by universities beyond the partnership as reference to update their undergraduate engineering profile.

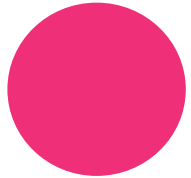


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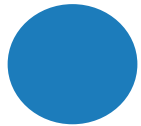
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Phase-1: I4.0 SUSTAINABLE TECHNOLOGIES ELIGIBLE FOR EDUCATION



Key Question

What are I4.0 technologies that can be implemented inline with the UN sustainability goals to be considered in engineering education?



I4.0 Technologies

What are I4.0 technologies?



I4.0 sustainability

What is the influence of I4.0 on the achievement of the SDGs?



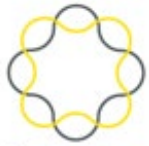
Sustainable I4.0 technologies eligible for education

What are the eligible contents for engineering education?

What is I4.0 ?



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I4.0 TECHNOLOGIES



Definitions

- **Industry:** transformation of materials into a product (**added value**)
- **I4.0** is meant to rapid transformations in the design, manufacturing, operation and services related to manufacturing systems or products.

I4.0 Enablers

1. *Industrial Internet of Things*
2. *Big Data & analytics*
3. *Cloud Computing*
4. *Simulation*
5. *Augmented Reality*
6. *Additive Manufacturing*
7. *Horizontal & Vertical System Integration*
8. *Autonomous Robots*
9. *Cybersecurity*

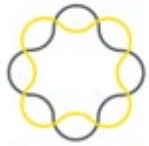
- **Collection of technologies**
- **Higher level classification**



How to bridge this gap ?



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IDENTIFYING I4.0 TECHNOLOGIES



Assign Enabler(s)
to group

2

Group's
discussion



Review the
Elements

4

Group's
discussion



Refine the
Elements

5

Individual
group



Identify the
Elements

3

Individual
group



Identify
enablers

1

Literature



What is the result ?



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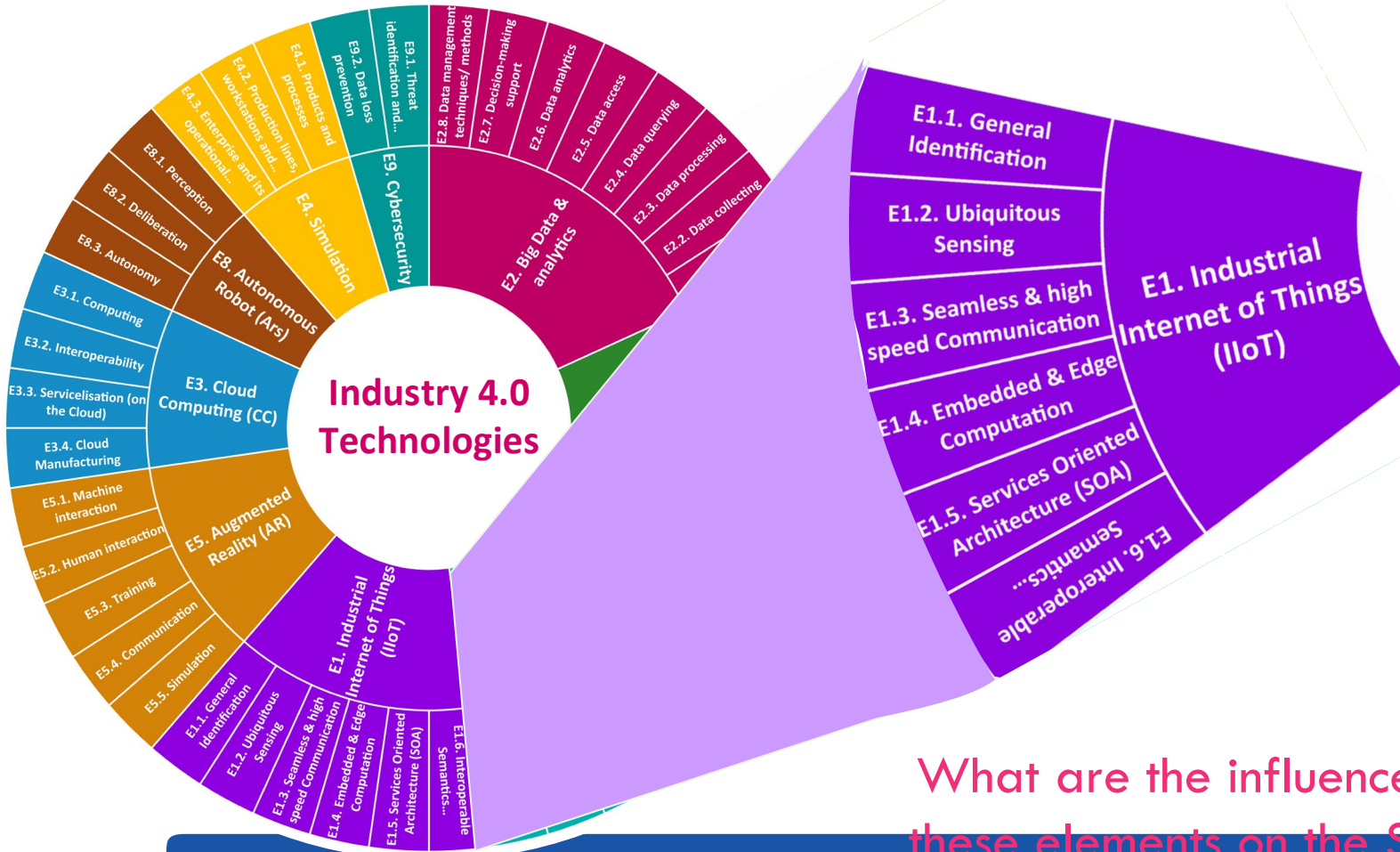


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14.0 ELEMENT TECHNOLOGIES



What are the influences of these elements on the SDGs ?



MAPPING METHOD



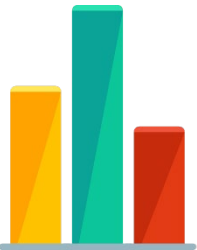
Questionnaire

Discuss the result

Design a measure

1

Group's discussion



2

Individual group



Aggregate Analyze

3

LBORO group



4

Group's discussion

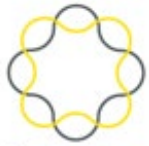


5



How to measure the influence ?



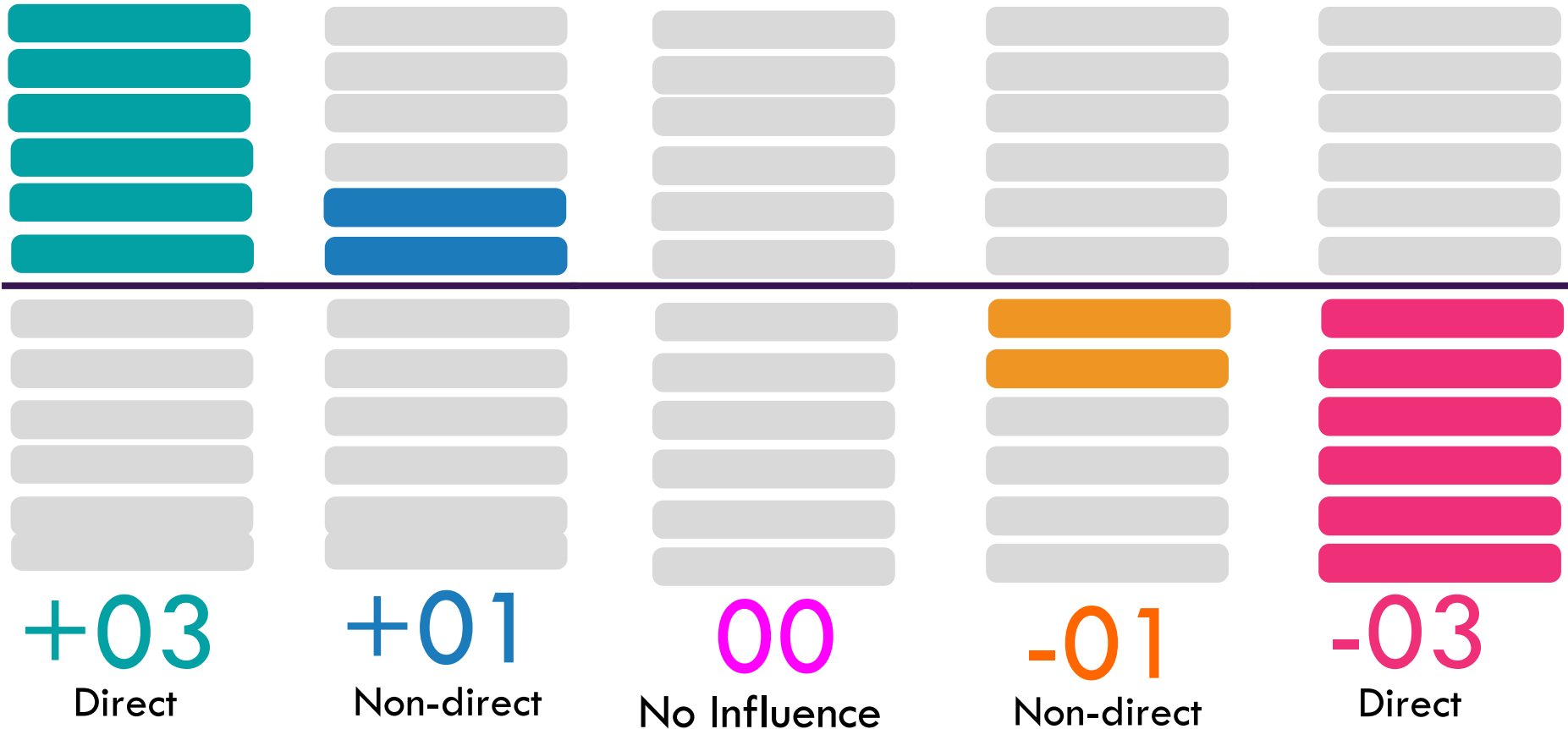


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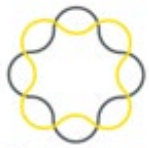


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INFLUENCE MEASURE



What is the result ?

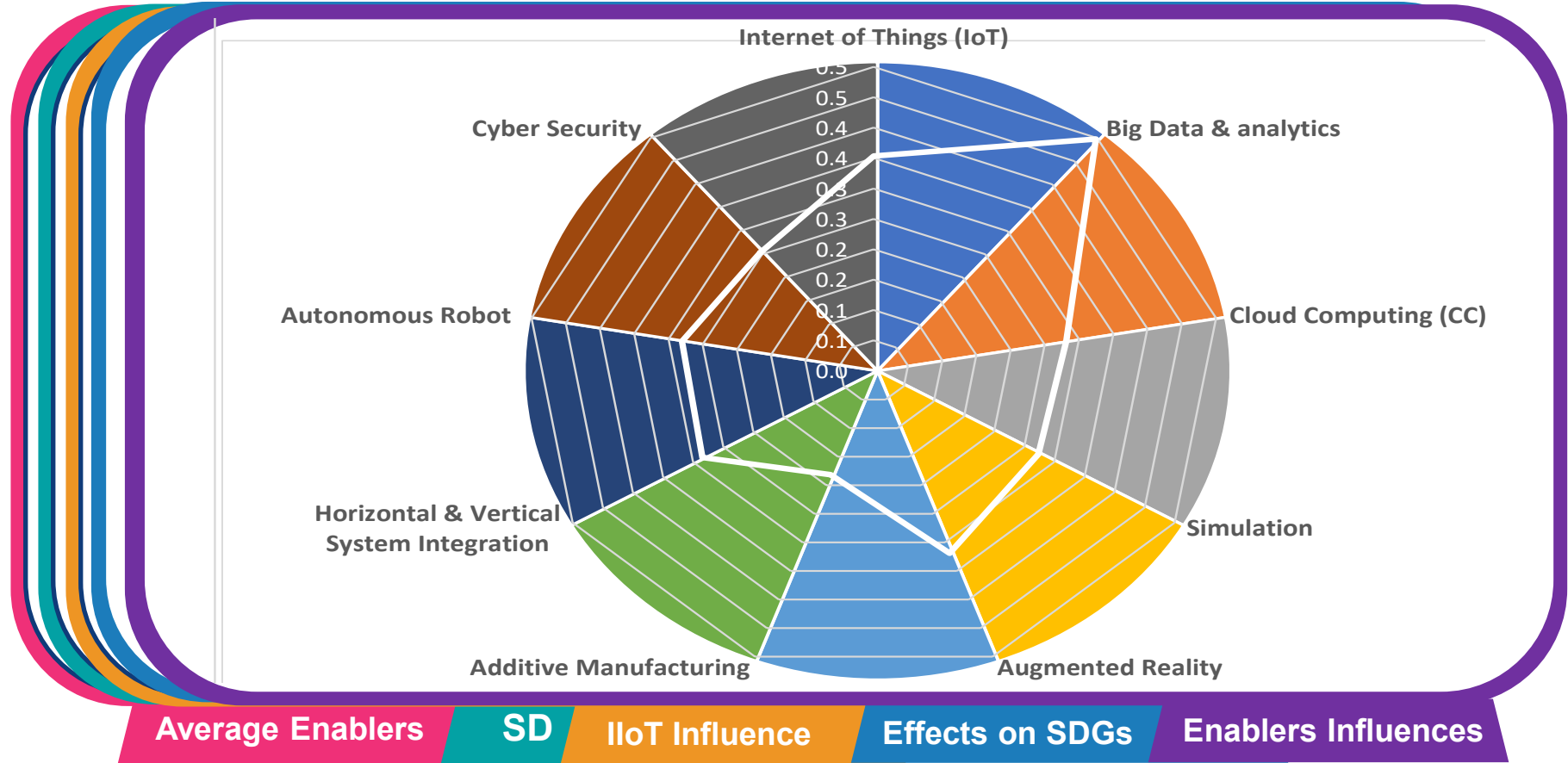


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MAPPING RESULT



What are the eligible I4.0 Sust. Tech. for Eng. education ?

RZESZOW, POLAND, 12 JUNE 2021



ELIGIBLE I4.0 SUST. TECH. CONTRIBUTIONS FOR ENG. EDUCATION



Huge contribution of I4.0

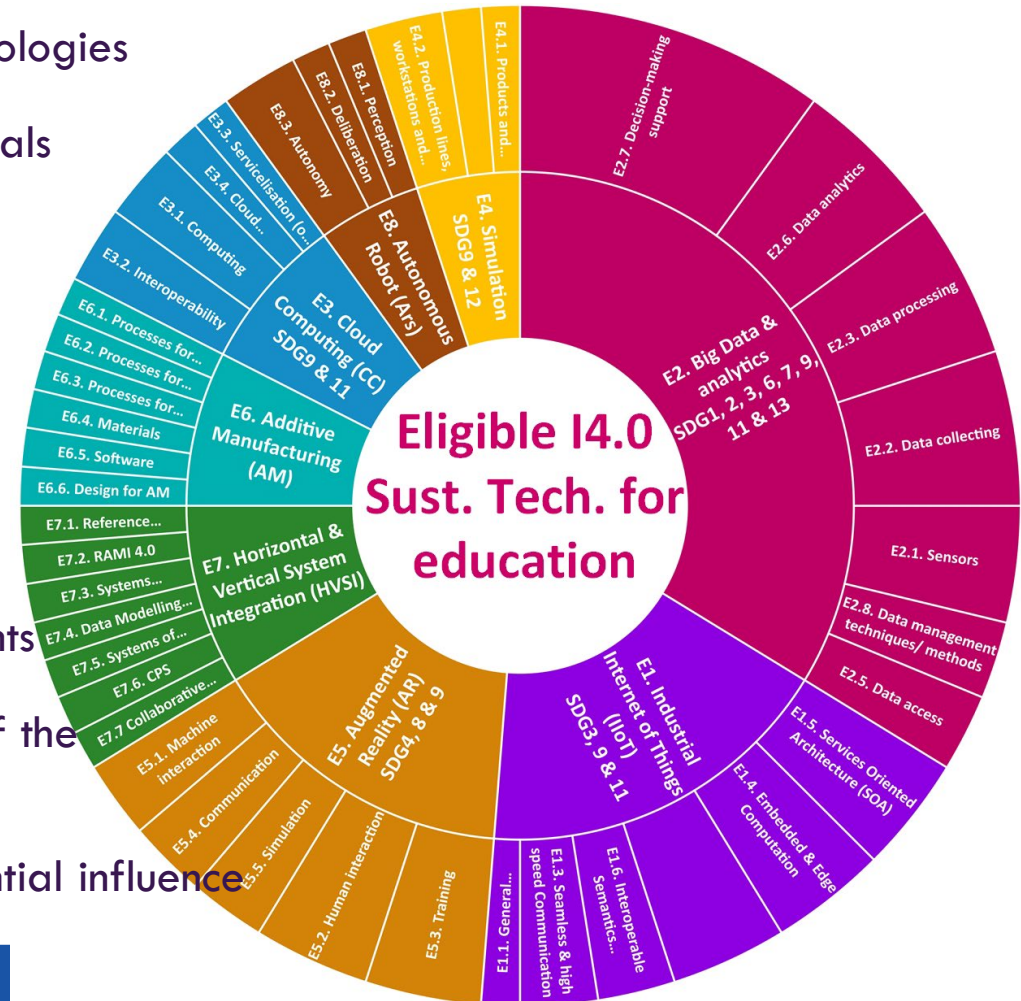
- Majority of the 44 element technologies influence most of the 17 goals.
- 748 combinations of elements-goals

Prioritize the contributions

- It is not possible to consider all contributions at once.
- Prioritize high influences
- An average score of +2 is selected as a cut-off.

Eligible contributions

- 11% of the highest effect elements-goals are selected.
- They are accountable for 25% of the influence.
- 41 elements are considered.
- It was believed to have a substantial influence on 11 goals





CONCLUSION & FUTURE WORK



01. 14.0 Elements Tech.

- 44 elements technologies
- Most technologies are not new
- Deployment way is the most important

02. Positive Influences

- Most of the effects are positive
- A consensus has been reached on most of the results

03. Effects on SDGs

- Highest is on goals related to industry
- Lowest is on goals related to social aspect

04. Eligible Tech. for education

- Huge contribution of the element-goals
- The highest influence combinations are prioritized to be considered in engineering education for the first step.

01. Technology maturity

- Identify technologies at high maturity level

02. Sust. engineering courses

- Sust. content development approach
- Sust. contents assessment approach

03. Expand the mapping

- Expand the expert's panel
- Investigate industrial experts' perspectives

04. Influence on individual SDGs

- Focus on Individual goals, particularly goals with less consensus





Output 2

- This activity 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 term 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.



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1. Introduction

RQ1: How to define the archetypes of engineers?



RQ2: How much is there of Sustainability in these archetypes?



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1.1 Sustainable Development Goals (SDGs)



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1.2 Sustainability in engineering educational framework

- **Teachers' course design:** despite good practices for courses design (e.g., [2], [3]), deep integration of sustainability into the core subjects appears to be lacking [1].

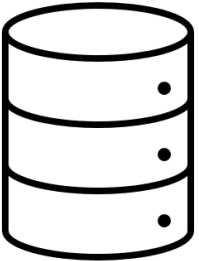


- **UNESCO and accreditation bodies:** despite numerous guidelines and standards on teaching the SDGs (e.g., [4]-[6]), a clear and objective understanding on how much a specific engineering is aligned with the SDGs is lacking.



1.3 Sustainability in engineering occupational framework

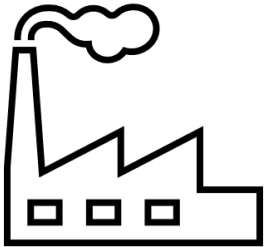
- **Organizations:** Although many organizations are interested in sustainable management and HSE (e.g., [8], [9]), a compact definition of what engineers are and how they could be associated with sustainability is lacking.



- **ESCO:** European multilingual database deserves attention when describing, identifying, and classifying professional occupations and skills as a result of a specific qualification [7].



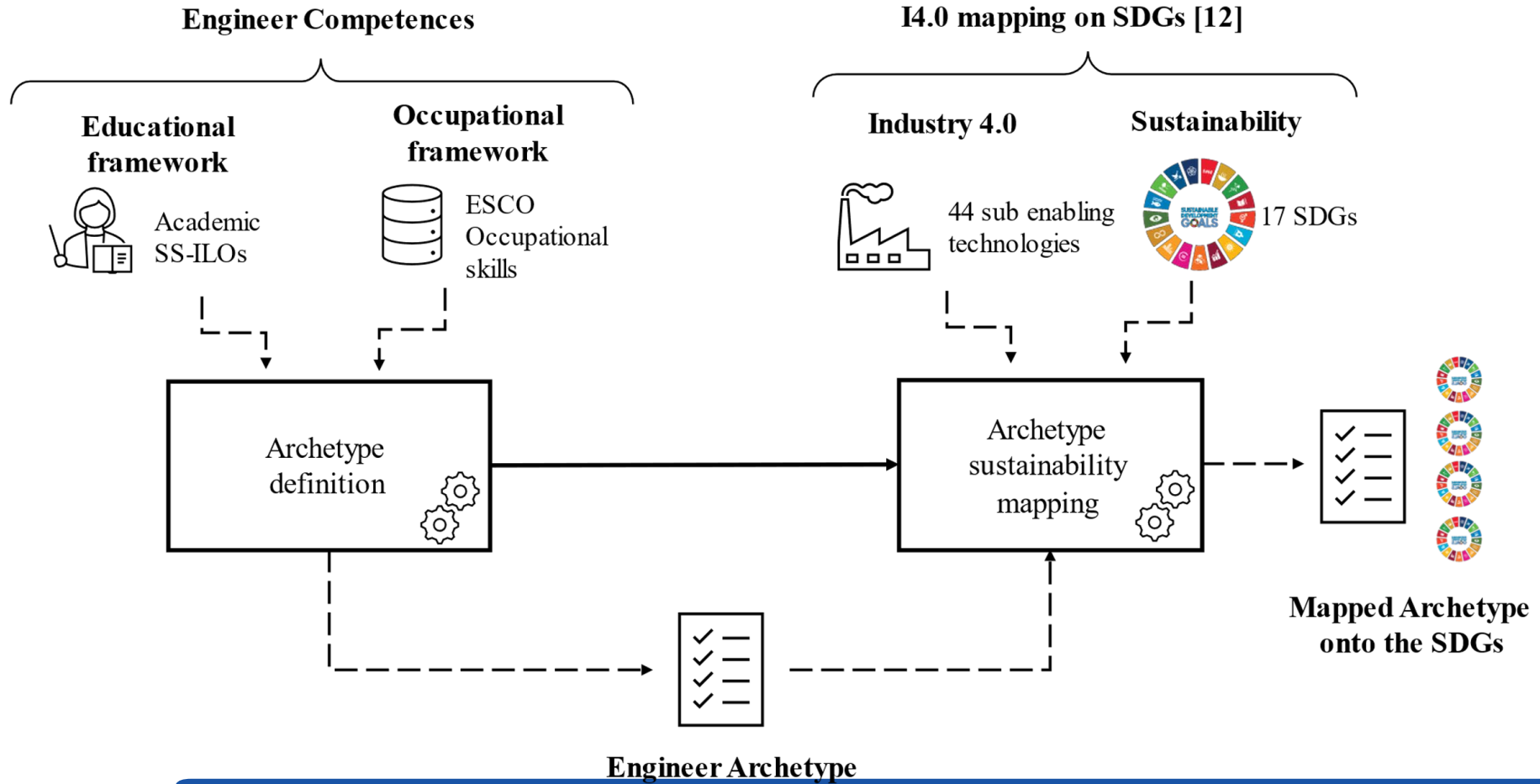
1.4 Industry 4.0 (I4.0)



- **I4.0:** new way of organizing the production methods by bridging the physical and the digital [10].



2 Methodology





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2.2 Archetype sustainability evaluation (2)

Engineer archetype:
Clusters of competences
(CL1-CLx)



Team
scoring

Aggregated scores:
I4.0 technology in Archetypes
(CL1-CLx vs. E1.1-E9.2)



vs.



Inferencing
algorithm

Results:
Archetype sustainability
(CL1-CLx vs. SDG1-SDG17)



vs.



Reference [12]:
I4.0 technology elements
(E1.1-E9.2)



vs.



Reference [12]:
I4.0 technology sustainability
(E1.1-E9.2 vs. SDG1-SDG17)

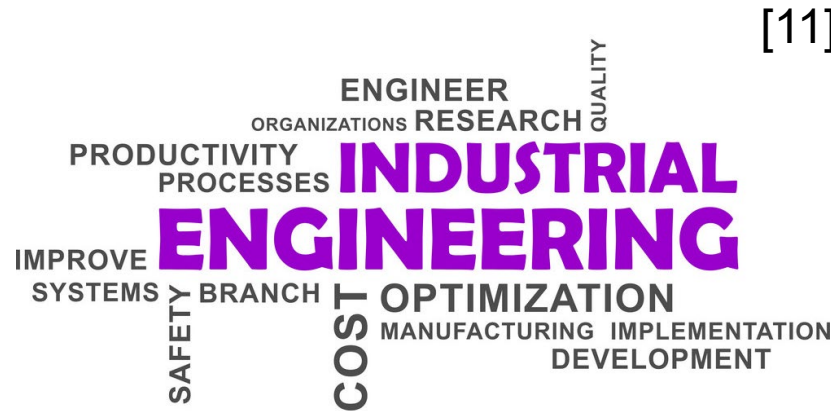


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3 Industrial engineer archetype case study



This professional profile output from these kinds of programs can be positioned in the overlapping of mechanical and management/production engineering.



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3.1 Industrial engineer archetype definition (1)

CL1: Manufacturing Processes.

CL2: Structure, Machine, and Product Design.

CL3: Production IT Tools Infrastructure.

CL4: Manufacturing Automation and Robotics.

CL5: Production Planning and Control.

CL6: Logistics and Supply Chain Management.





trial engineer archetype n (2)

CL1: Manufacturing Processes

- Design and Analyze a plan or specification for the design of conventional industrial production systems (e.g., cutting, molding, deformation, welding).
- 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.





Industrial engineer archetype ability evaluation

Industrial Engineer Archetype						Industry	Sustainable Development Goals																	
CL1	CL2	CL3	CL4	CL5	CL6		4.0	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
1.00	0.75	4.00	7.00	1.75	3.25	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
3.00	0.25	1.50	2.25	1.00	1.00		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
2.25	0.75	5.25	3.75	0.25	1.00		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
2.25	1.00	5.25	3.25	0.75	0.25		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
0.75	0.25	1.00	1.75	0.25	1.00		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
0.75	0.25	0.75	1.75	0.75	0.25		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
1.50	2.75	3.25	3.75	3.00	1.00	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
0.75	1.00	3.75	3.25	3.25	4.75		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
0.75	0.75	1.50	1.50	5.50	5.00		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
0.25	0.75	3.75	1.00	0.75	0.25		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
0.25	0.75	3.25	1.00	0.75	0.25		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
0.75	2.25	3.00	2.25	6.00	3.00		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
4.50	2.25	3.00	4.75	7.00	4.75	E3	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
0.75	2.50	3.25	1.00	1.50	2.75		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
0.75	2.50	4.00	2.25	0.25	0.75		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
0.25	0.75	5.25	0.75	0.25	0.25		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	0.10	0.33
0.75	0.25	5.00	0.75	0.25	1.50		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
0.75	0.75	3.50	1.00	0.25	0.75		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
7.00	6.00	6.00	3.00	5.50	2.00	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
6.00	3.75	4.50	3.00	4.00	7.00		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
3.50	1.75	3.25	3.00	4.00	1.75		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
0.75	3.00	1.50	1.00	0.25	0.25	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
0.50	1.00	1.75	0.75	0.25	1.00		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
2.50	0.50	3.25	0.75	1.00	0.50		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
0.75	1.00	5.25	2.25	0.25	1.00		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
2.50	5.25	5.25	2.25	0.25	1.00		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
7.00	2.75	1.75	0.25	1.00	0.25		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
7.50	2.75	1.25	0.25	1.00	0.25	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
5.50	2.75	1.25	0.25	1.00	0.25	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
4.00	5.00	0.25	0.25	1.00	0.25	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
3.50	7.50	4.50	1.00	1.00	0.25	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
3.00	4.50	3.75	1.00	0.25	0.25	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
0.25	0.25	5.50	2.50	1.00	1.00	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
0.25	0.25	3.00	0.50	0.50	0.50		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
0.75	0.25	7.50	1.50	5.50	1.25		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
1.00	0.50	5.50	1.00	4.75	0.25		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
0.25	0.75	4.00	3.00	0.75	1.00		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
0.75	0.75	4.50	1.50	1.00	1.00		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
0.75	0.75	1.50	0.50	0.75	2.25	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	
1.00	0.75	0.75	6.00	0.25	0.50	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
1.00	0.75	0.75	6.00	0.25	0.50		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
1.00	0.75	0.75	7.50	0.75	0.33		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
0.33	0.25	3.50	1.00	0.25	0.50	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
0.25	0.25	3.50	1.00	0.25	0.50		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



3.3 Analysis of the results of the industrial engineer case study (1)





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3.3 Analysis of the results of the industrial engineer case study (2)



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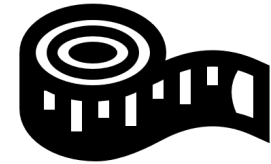
4 Discussion and Conclusion

The proposed methodology:

Promote the culture of measuring and monitoring sustainability in engineering disciplines

Has been validated by defining a standard industrial engineer archetype

Stimulate interdisciplinarity

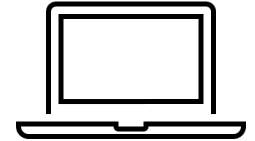




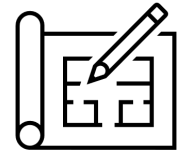
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5 Future work

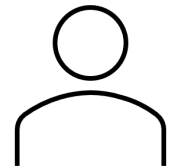
Automate the archetype definition through text mining approach.



Redesign archetypes collaboratively



Extend mapping the SDGs to a **general archetype** without using the I4.0 technologies as a bridge



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Output 3

- This activity addresses the identified gap and mismatches by developing learning material for different courses which includes the technologies and applications identified in O1 and organizes them according to the results of O2.
- Courses will include:
 - Specifically designed, up to date, learning content-case studies featuring the existing implementation of industry 4.0 technology in industry
 - Specific reference to the sustainability dimension: this is a very specific and innovative requirement in the Maestro initiative.
- Each course will be designed and described according to Constructive Alignment (CA).



Output 4

- 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 forming the consortium.
- This will be 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 will be organised (see C2).



Output 5

- This activity is targeting the exploitation of the project results within the consortium beyond the duration of the initiative.
- Single institutions will not have enough resources to maintain excellent learning experiences for student across the whole spectrum of technologies emerging from the fourth industrial revolution. An additional requirement comes from the inclusion of the sustainability dimension.
- Cooperation becomes a fundamental part of keeping an excellent education portfolio. Maestro partners will, at this time of the project, know each other's expertise very well. Thus, they will be in position to formulate cooperation requirement that mutually strengthen each institution.
- The expected results of this will include, but - not be limited to: joined profiles, double degrees, exchange of teaching staff, exchange of students. These activities will, on the long run, promote sharing and dissemination of excellence across the Union. They can also be the base of further cooperation beyond the HE involved in the initiative.



Example on Virtual Reality

- Virtual Reality, or VR, is a family of technologies defined in the 60s that aims at mimicking reality through computers with different purposes.
- VR is usually classified according to the level of user immersion achieved: this work focus on fully-immersive VR.
- VR has attracted increasing attention between academic and practitioners during the last decade due to technological progresses that achieved high reliability and relatively low cost.
- VR potential to visualize information, replace physical presence and stimulate interaction make of this technology an essential part in the toolbox of future engineers.



Challenges

Higher Education Institution must align their curricula to fulfill this purpose.

VR can be a support to enhance the learning process itself.



Research Objective

Analyse the impact of fully-immersive VR technology on an average production engineering curricula based on the educational offer at KTH Royal Institute of Technology in Stockholm, Sweden.



Method

Average production engineering curricula has been established starting from the didactic offer at KTH royal Institute of technology:

- 5 mandatory and 7 elective courses selected for a total of 87 credits
- Courses described through Intended Learning Outcomes (ILO)

Characterization of the VR impact on single ILO through literature review and discussion with course responsible/expert in the field. Two type of VR impact:

- *Qualitative measure*. Two possibilities: **technological** impact if VR should be among the topic of the ILO, i.e. the ILO should be completed with novel VR technology; **educational** impact if VR could be a mean of teaching.
- *Quantitative measure*. Three possibilities: **High**, when the introduction of VR has to be a priority as it is significantly better than the incumbent approach; **Medium**, when VR has some benefits compared to the incumbent approach; **Low**, when VR use does not significantly improve the current approach.



Results

Course ^a	MG2029 Production Engineering - Planning and Control	
	ILO	Impact
	Explain fundamental principles used in traditional production planning and control systems	Tech-Low
	Develop an aggregate plan for manufacturing of a multi-component product	Tech-Medium
	Suggest master production schedule and material requirement plan for a given aggregate plan	Tech-High
	Apply the proper inventory control method for a product with known demand	Tech-Medium
	Choose the best operations scheduling approach to optimize certain shop floor performances	Tech-High
	Describe the principles of push and pull control policies	Tech-Low
	Characterize the fundamental principles of lean philosophy and tools	Tech-Medium
	Utilize appropriate lean tools to continuously improve shop floor performance	Tech-High
	Apply value stream mapping for current and future states to a given case study	Tech-High

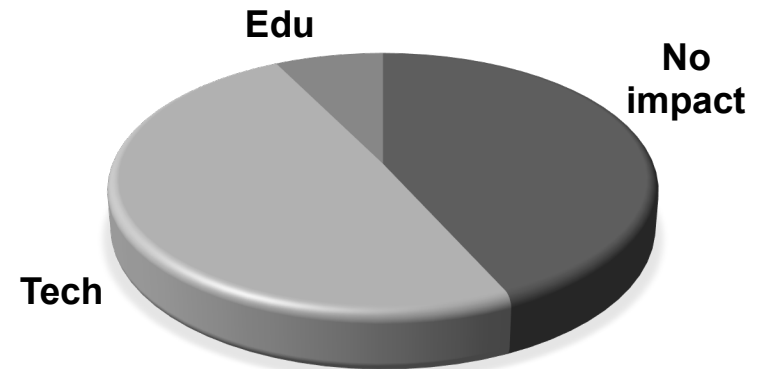
Results

Course ^a	MG2130 Modelling and Simulation of Industrial Processes	
	ILO	Impact
Explain the fundamentals of “digital factories” and “digital manufacturing”		
Explain factory planning, process planning and flow planning, and relationships between these three domains		Edu-High
Explain basic activity steps within these three domains		Edu-High
Use specific software to develop factory layouts with buildings, manufacturing/assembly systems and factory assets:		Tech-High
Use specific software for CAM – Computer Aided Manufacturing to develop and simulate manufacturing processes/operations		Tech-High
Use specific software for event-driven flow simulation to develop a balanced manufacturing flow within a factory		Tech-High
Apply the knowledge described above for a given product, in order to develop a model which can be used in realization of a factory		Edu-High

Discussion

- The 12 courses analysed have a variable number of ILOs for a total number of 81 single ILOs.
- The characterization process shows that VR holds potential to impact 46/81 of these basic educational unit.
- This means that more than half of the teaching and learning activities in the analysed course could be affected in the coming year by VR.
- A vast majority of the expected impact are technological.

VR impact on TPRMM program ILOs



Graph 1 displays these results.



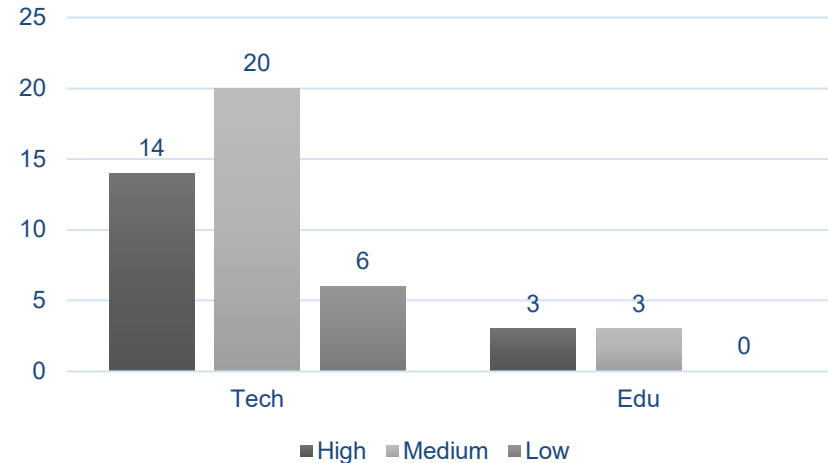
Discussion

The prominent types of quantitative impacts are then Medium or High while Low is less common.

This suggests that, when applicable, VR has a positive effect on the related technical and/or educational task.

The 17 High quantitative impact are considered to be areas where VR will hold an important advantage on current methods. As expected the ILOs with High impact are in the domain of simulation and evaluation beforehand of different kinds of engineered systems.

Quantitative impact of VR on ILOs





Possible contribution/cooperation

- Share experience and practices in your education that are related with implementation of sustainability UN agenda
- Participate to the multiplier events
- Cooperation on definition of curricula: for staff active in education development