Didactic Guidelines

Project title: Deep Tech & Robotics for Human-Centered Manufacturing Systems
Project ancronym: DRUMS
Project code: 2023-1-DE02-KA220-VET-000155846

Co-funded by
the European Union

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1. Project Introduction

The DRUMS project (Deep Tech & Robotics for Human-Centered Manufacturing Systems) is a transformative initiative aimed at reshaping the European manufacturing sector through the integration of cutting-edge technologies, such as deep tech, robotics, and artificial intelligence, into production systems that prioritize human well-being. Aligned with the principles of Industry 5.0, the project responds to the growing need for a human-centric approach in manufacturing processes, moving beyond traditional efficiency and cost-reduction goals. DRUMS seeks to create an environment where workers play a central role, improving their skills and productivity while enhancing overall operational sustainability.

One of the key pillars of DRUMS is the development of a comprehensive training framework designed to equip managers, workers, and students in the manufacturing sector with the skills necessary to interact effectively with advanced technologies. By focusing on the integration of deep tech and robotics, the project addresses the skills gap in European manufacturing, aiming to foster a high-value workforce that can drive the twin transitions of digitalization and sustainability. Through a range of innovative training resources, DRUMS will provide educational content for learners and capacitation materials for trainers, emphasizing practical, real-world applications in manufacturing environments across six European countries.

Furthermore, DRUMS aims to ensure the long-term sustainability of its outcomes through the creation of blueprints and action plans that will support ongoing innovation in the sector. By leveraging insights from external experts and implementing pilot actions involving 150 participants, the project aspires to create a scalable and transferable methodology that can be applied to other industries.

As for the specific objectives of WP2 (Didactic Guidelines & DRUMS Methodology), this work package focuses on supporting VET staff with updated resources for practical training in manufacturing. WP2 aims to create didactic guidelines and a human-centered methodology, which will include both existing and newly developed training materials. These resources will help trainers and learners integrate new manufacturing technologies, ensuring that the learning scenarios are human-centered and transferable to the workplace.

2. Executive summary

The DRUMS Didactic Guidelines are designed to provide educators and trainers with a robust framework for equipping learners with the skills and knowledge needed to thrive in the context of Industry 5.0. These guidelines emphasize sustainability, circular economy principles, and cutting-edge technologies such as AI, robotics, deep tech, and manufacturing. By combining innovative pedagogical strategies with real-world applications, the guidelines aim to inspire learners to address industrial challenges through creativity, critical thinking, and collaboration.

The structure of the guide is modular, enabling flexibility and adaptability for various educational contexts. Each module includes clearly defined objectives, and practical exercises, covering essential themes from sustainability and technological innovation to the social and ethical implications of Industry 5.0. Additionally, the guidelines provide trainers with tools and resources to facilitate active learning, group activities, and case studies. This comprehensive approach ensures learners are not only prepared for technological advancements but are also capable of contributing to sustainable and inclusive industrial growth.

Furthermore, the guidelines emphasize a learner-centered approach, encouraging educators to foster environments where participants can actively engage with the material and collaborate effectively. By incorporating interdisciplinary content and a focus on practical application, the guidelines serve as a bridge between theoretical knowledge and industry needs. This ensures that learners are empowered to innovate responsibly, promoting a future where technological progress aligns with societal and environmental well-being.

3. Survey Results

The DRUMS survey, conducted between May and July 2024, explored various perspectives from participants in the manufacturing sector regarding green transitions, digital innovations, and emerging technologies. With 146 respondents, the goal was to capture insights on the importance of technology training, the green and digital transition of the manufacturing industry, and the skills perceived as essential for future career development.

1. Describe your role:

Between them the majority were VET students 49.66% following then VET teachers 17.93%, workers 14.48%, CEO 8.97% and Officer/Manager 8.28%, of the manufacturing industry.

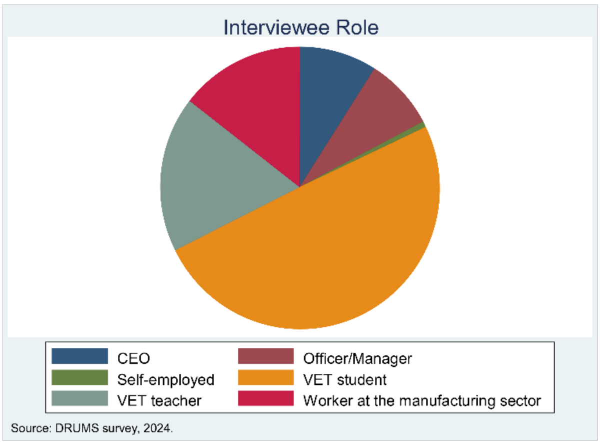


Figure 1: Interviewee Role

2. To what extent do you agree with the following statement?

The future of the manufacturing industry lies in the green and digital transition.

The level of agreement is quite significant, 65.75% agree and 26.03% totally agree with the statement, and only 8.22% disagree or totally disagree. Across countries, there is also a consensus. In Slovenia, the 100% of respondents agree or totally agree with the statement, in Germany 93.64%, in France 90%, in Croatia 90%, in Austria 88.89% and in Spain 88.57%.

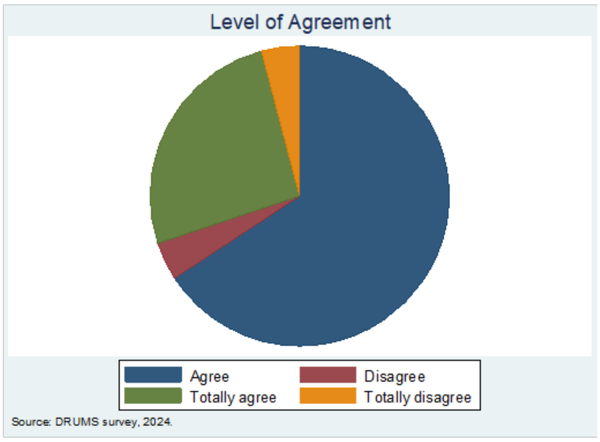


Figure 2: Future of Manufacturing: Green and Digital Transition Agreement

3. Do you think training in emerging technologies would benefit your current role?

The level of agreement is overwhelming, while 52.74% and 43.15% state It would be very and somewhat beneficial respectively, just 4.1%, a small minority, do not believe in it. As in the previous question, we find there is a huge consensus across countries. The highest agreement is seen for those respondents of EITM (France) and Slovenia with 100% stating training in emerging technologies is very or somewhat beneficial, followed by Croatia 97.50%, Spain 97.14%, Austria 94.45 and Germany 86.36%.

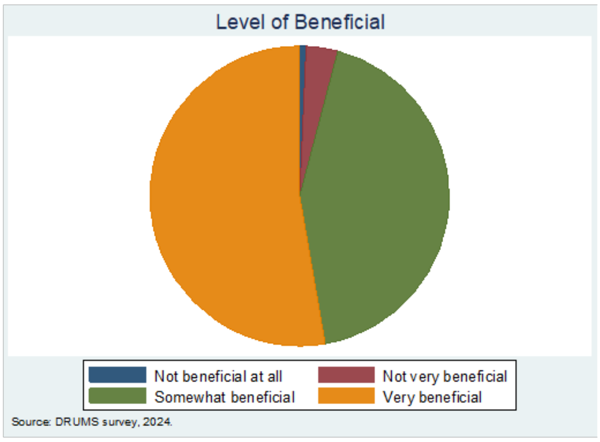


Figure 3: Perceived Benefits of Technology Training

4. What is your preferred learning style?

Regarding the learning style preferences, the most popular option is "hands-on," preferred by 33.56% of respondents. This is followed by "all of them," chosen by 29.45%. "Interactive" learning is the third most favoured style, with 19.86% of the respondents preferring it. This distribution highlights a strong preference for practical and versatile learning approaches.

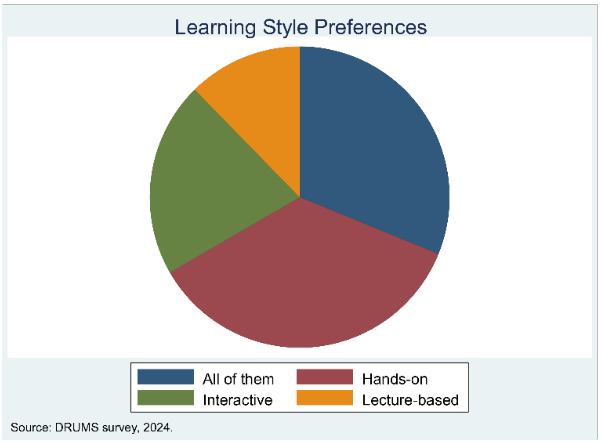


Figure 4: Learning Style Preferences

5. How many hours could you dedicate per week to do a training program?

Regarding the numbers of hours interviewees would dedicate to do a course, the 20.42% would spend up to 5 hours, the 16.20% up to 2 hours, the 10.56% up to 3 hours and a 11.27% up to 4 hours. As shown in the graph, the number of people willing to invest between 6 to 10 hours per week is 23.24%, and the percentage of respondents disposed to invest more than 10 hours in taking a course is minimal, 5.62%.

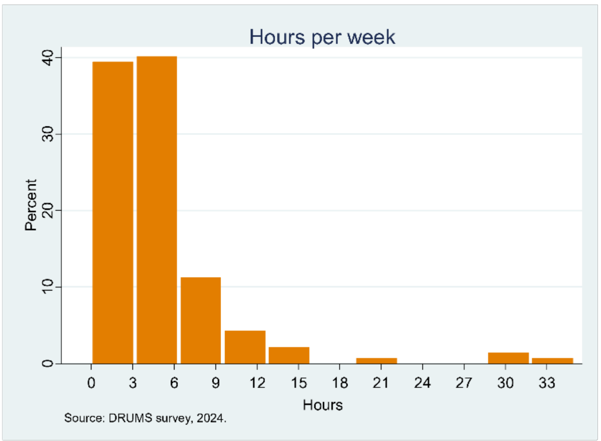


Figure 5: Weekly Training Hours Commitment

6. How long should an ideal training program last, in weeks, to meet your needs?

Regarding the number of weeks, they would dedicated to do a course, the most popular option is 5 weeks, chosen by 19.72% of the interviewees, followed by 4 weeks (15.49%) and 3 weeks (10.56%).

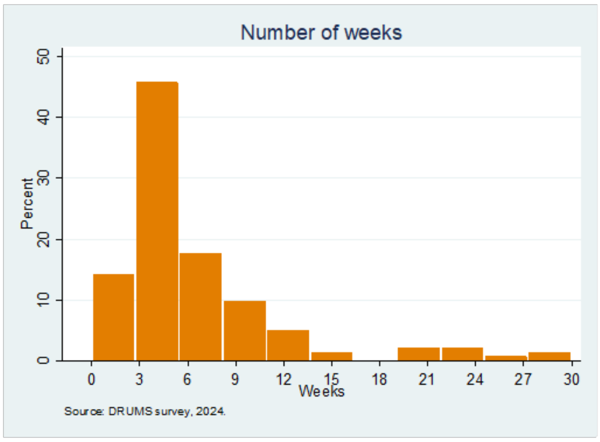


Figure 6: Ideal Duration of Training Programs

7. Are you familiar with eco-design or circular business models?

Concerning how familiar with eco-design the interviewees are, the largest segment, 41.10%, and 28.77% described themselves as slightly familiar and not familiar at all respectively, indicating a significant gap in knowledge and awareness about eco-design among the respondents. This suggests a need for increased education and training to ensure that more individuals are adequately informed and capable of implementing eco-design principles in their work.

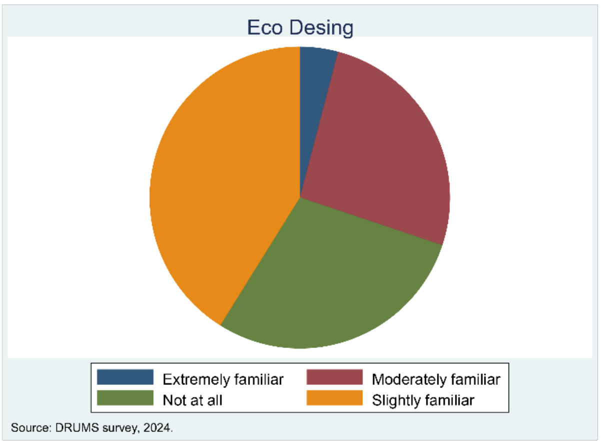


Figure 7: Level of familiarity with circular design

The following are the results for each of the skills from the two questions, 8 and 9, presented simultaneously. The orange bar charts correspond to the results of question 8, while the blue bar charts represent the results of question 9.

8. Of the following skills, rate how important you think they are for your educational and professional career. Being 1 Not important at all and 10 Very important.

9. Of the following skills, do you think they are missing in the training program or your department? Being 1 strongly missing and 10 strongly integrated.

User Interface

Regarding the importance given to User-Interface (UI), we find a variety of opinions. The 29.66% of respondents consider user interface knowledge to be very important (ratings of 8-

10). The moderate ratings (4-7) show some alignment, with 40.68% considering the topic moderately important, and 29.66% state it is not relevant for them (rating 1-3). In contrast, 68.97% believe their academic programs do not cover this topic (ratings of 1-5).

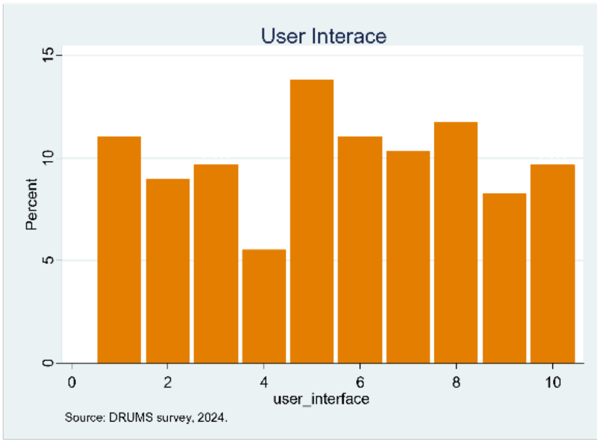


Figure 8: Level of importance for UI

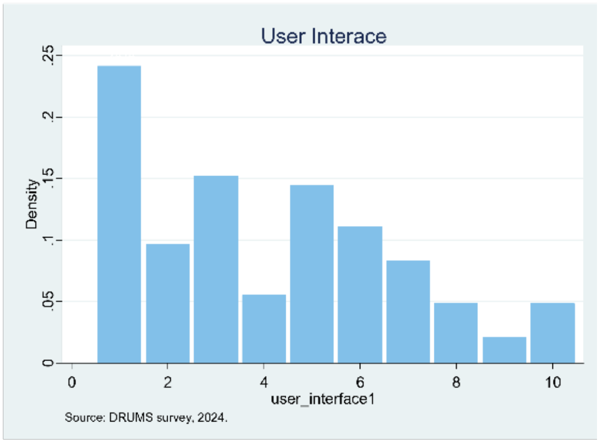


Figure 9: Content Gap for UI

Robotics

A majority of respondents (56.25%) consider robotics knowledge to be of high importance (ratings of 7-10). In contrast, only 28.47% believe that their academic programs provide extensive coverage of this topic (ratings of 7-10).

The data reveals a clear gap between the importance placed on robotics knowledge by respondents and its integration into their academic curricula. While a majority see it as highly important, less than a third feel it is adequately covered in their studies. Addressing this gap could enhance the relevance and applicability of academic programs to better meet the expectations and needs of students.

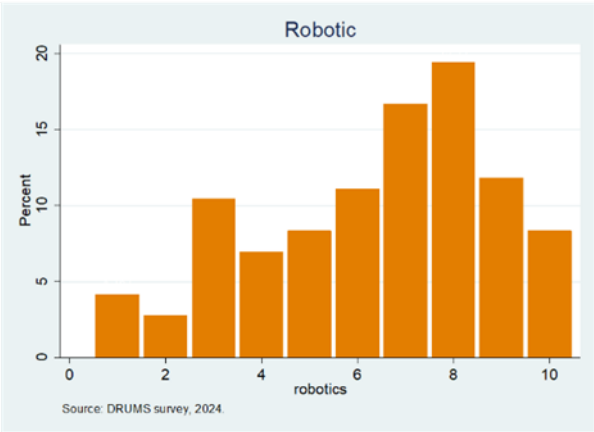


Figure 10: Level of importance for Robotics

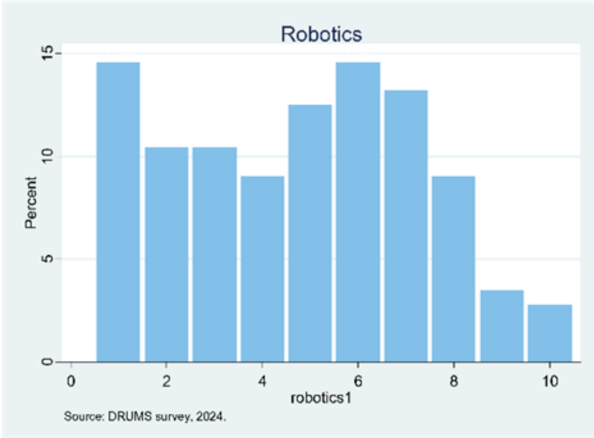


Figure 11: Content Gap for Robotics

Internet of things

The data indicates that Internet of Things (IoT) knowledge is highly valued by the majority of respondents, with 67.36% rating its importance between 7 and 10. This highlights a strong recognition of the relevance of IoT in contemporary education and professional development.

In contrast to its perceived importance, only 28.87% of respondents (rating of 7-10) feel that their academic programs provide extensive coverage of IoT knowledge. This suggests a significant gap between what is considered important and what is being taught.

To better align academic offerings with student expectations and the evolving demands of the workforce, educational institutions might consider enhancing their curricula to include more comprehensive and in-depth coverage of IoT concepts and applications.

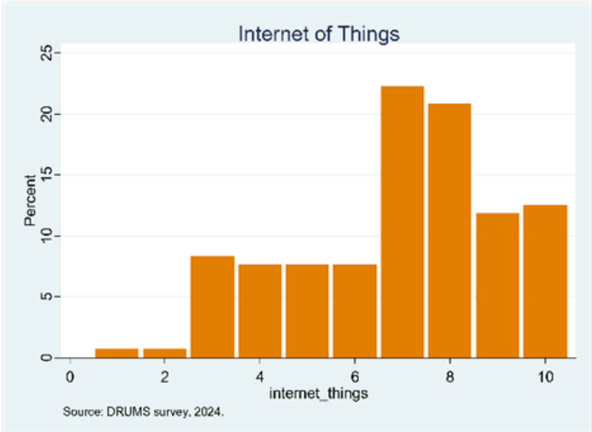


Figure 12: Level of importance for IoT

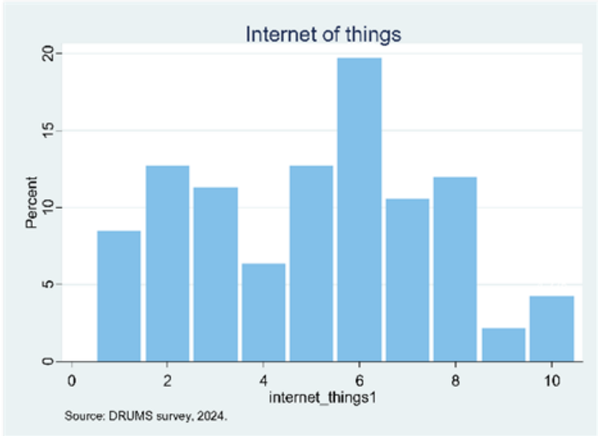


Figure 13: Content Gap for IoT

Machine Learning

The data shows that Machine Learning (ML) knowledge is highly valued by respondents, with 60.27% rating its importance between 7 and 10.

However, only 29.66% of respondents feel their academic programs provide extensive coverage of this topic. Furthermore, a significant 38.61% of respondents rated the presence of machine learning content in their curricula as minimal (1-3). Addressing this gap could better prepare students for the growing significance of these technologies in various fields.

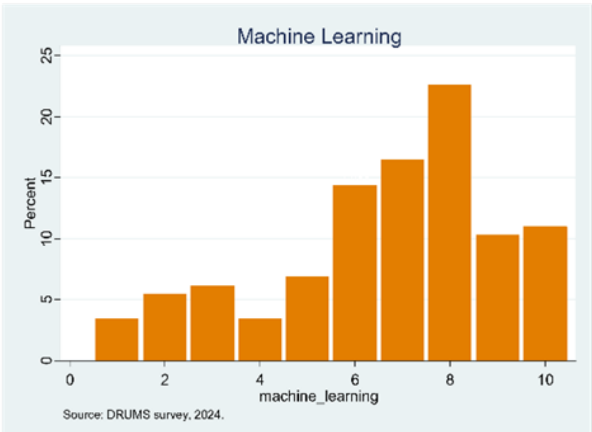


Figure 14: Level of importance for ML

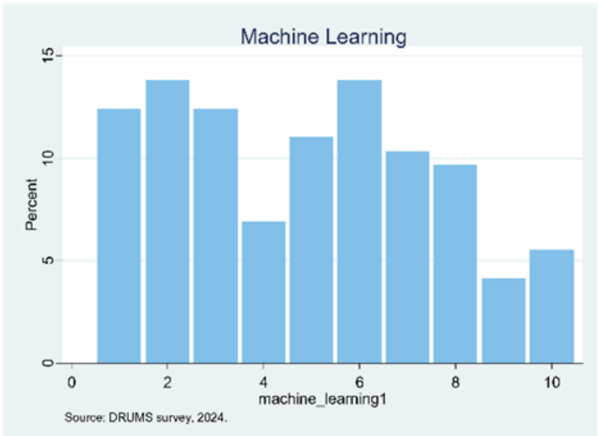


Figure 15: Content Gap for ML

Artificial Intelligence

The data shows that AI knowledge is highly valued by respondents, with 59.30% rating its importance between 7 and 10. This underscores a strong recognition of AI significance.

These results reveal that only 19.32% of respondents believe their academic programs extensively cover AI knowledge, while a significantly larger portion (49.65%) feel that its presence is minimal. This indicates a substantial gap between what is considered important and what is being taught. These results highlight a major lack of comprehensive education on this subject in current academic programs.

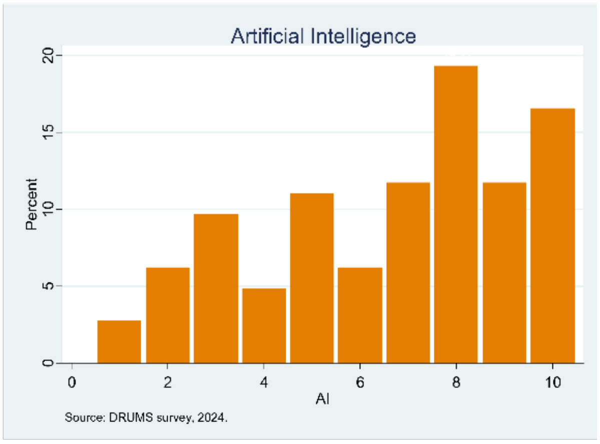


Figure 16: Level of importance for AI

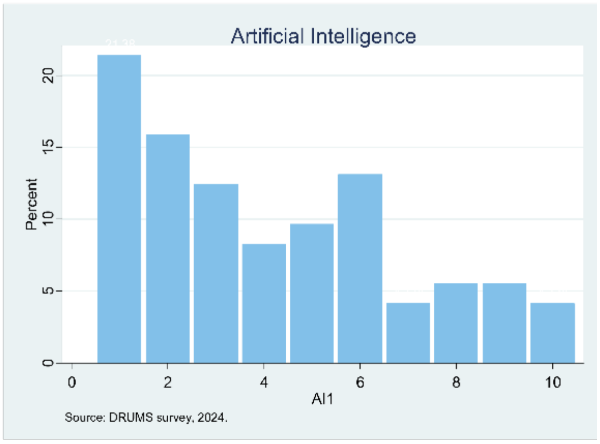


Figure 17: Content Gap for AI

Cloud Computing and Blockchain

The data shows that Cloud Computing and Blockchain (CCB) knowledge is moderately valued by respondents, with 36.62% rating its importance between 7 and 10. This suggests a slightly recognition of the relevance of these technologies in the education system.

A notable 50.00% of respondents rated the presence of cloud computing and blockchain knowledge in their curricula as minimal (1-3).

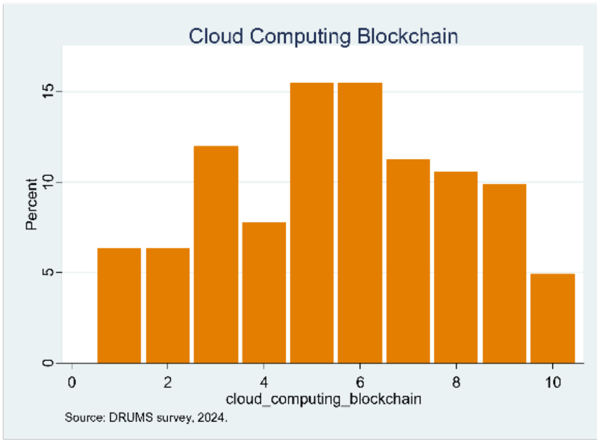


Figure 18: Level of importance for CCB

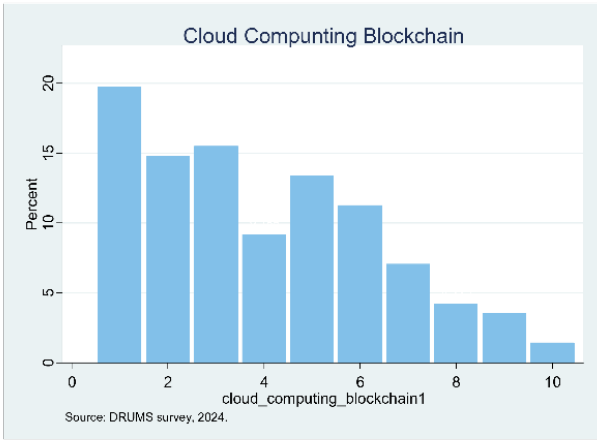


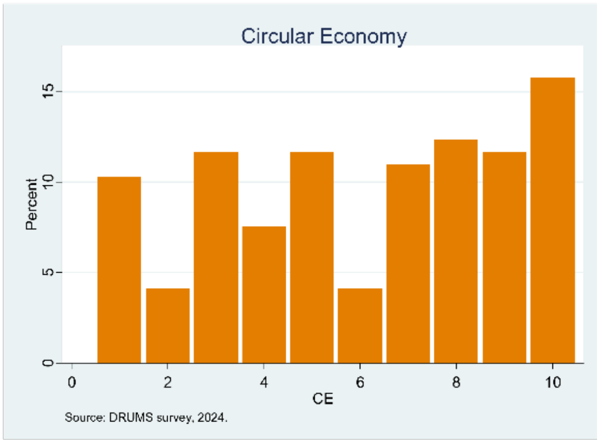
Figure 19: Content Gap for CCB

Circular Economy

The data shows that Circular Economy knowledge is highly valued by respondents, with 50.68% rating its importance between 7 and 10. This suggests a recognition of the relevance of Circular Economy.

Despite the importance placed on Circular Economy knowledge, only 25.52% of respondents feel their academic programs provide extensive coverage of this topic, and 37.94% of respondents rated the presence of Circular Economy knowledge in their curricula as minimal (1-3). This indicates a significant gap between what is considered important and what is being taught.

The survey highlights a clear discrepancy between the perceived importance of Circular Economy knowledge and its relatively inadequate presence in academic programs. Addressing this gap could better prepare students for the growing significance of sustainable practices in various industries.



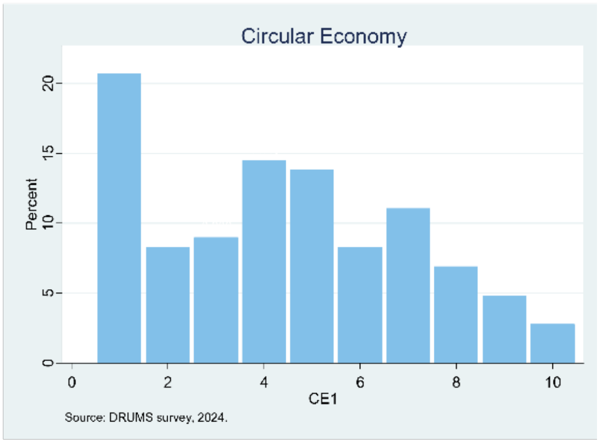


Figure 20: Level of importance for CE

Figure 21: Content Gap for CE

Conclusions

The survey results reveal a strong consensus regarding the importance of training in emerging technologies, with a significant majority finding it beneficial. Respondents from different countries overwhelmingly support the green and digital transition in manufacturing. However, there are notable gaps between the importance placed on specific skills, such as artificial intelligence and machine learning and their integration into academic programs. This discrepancy highlights the need for educational institutions to align their curricula with the demands of the modern workforce.

4. Interview results

This document presents the results of ten interviews conducted between May and July 2024 across the countries belonging to the consortium to assess the integration of advanced technologies such as artificial intelligence (AI), robotics, and deep tech into educational and industrial practices. The discussions centered around the growing need for hands-on training, the challenges associated with incorporating cutting-edge innovations, and the relevance of sustainability through circular economy principles. These insights reveal the current state of educational curricula and industrial practices, highlighting the gaps and opportunities for improvement in technological and environmental education and workplaces.

The results from many countries suggest the growing importance of integrating advanced technologies like AI, robotics, and deep tech into educational curricula, especially when it comes to training and more practical material. However, there is still a noticeable gap in providing adequate training in this area, with most of the existing education focused primarily on robotics.

“We don't have that much training material in this area yet, so we can see that there is a need.”

“We had only on robotics a professional 2-day training for Wittmann Battenfeld robots how to use them, program etc. for daily work inside the production”

Moreover, the discussion highlights several key challenges related to the integration of artificial intelligence (AI), robotics and so on in the industry and the necessity of staying up-to-date with the latest research advancements. Firstly, it emphasizes the importance of continuous training for workers, especially due to the rapidly evolving nature of technological innovations in this field. Keeping the knowledge and skills of technicians and industry professionals up to date requires ongoing effort and significant resources.

“One of the main challenges is keeping up with the newest research findings. The field is highly dynamic, with new breakthroughs happening regularly. Staying current requires significant effort and resources, and ensuring our employees are always up-to-date is an ongoing challenge.”

Additionally, the challenge that companies face in attempting to implement structural changes necessary to integrate new technologies such as AI is also noted. These changes not only demand considerable financial investment but also require an adaptation of internal processes. This challenge is even greater for small and medium-sized enterprises (SMEs), which often have more limited resources and flexibility compared to larger corporations.

“Probably the biggest challenge, which I think that everybody is facing is finding opportunities to really implement AI within their area of industry”

“I think that for about 10, 12 or 14 years it has started to be implemented, especially in larger companies, in SMEs and small companies it is more complicated to implement because of the cost involved, the initial investment.”

It's important to highlight that the circular economy is recognized as an important concept across various industries and educational programs in all countries. Spain, Germany, Croatia, Austria, and France all discuss the integration of circular economy principles into their educational programs or company practices. This includes training on sustainable practices, waste management, and the reuse and recycling of materials. However, although they recognize the importance of the concept, there is still a consensus that much more awareness and training are needed to fully implement and benefit from circular economy practices.

“Educating workers and students about the circular economy is crucial. It promotes more sustainable practices and helps lower environmental impacts.”

“I'm sure there's still a need to intensify this and get away a bit from the thinking that I see among technicians, that climate protection is the job of some last generation or some other weirdo and they have to take care of the real world”

There is a shared preference for hands-on, practical, and interactive learning methods. In most countries, there is a shared preference for practical, hands-on learning methods over purely theoretical approaches. This reflects a broader educational trend towards experiential learning that enhances engagement and retention of knowledge.

“Our workers definitely prefer hands-on learning. Practical, experiential methods are the most effective for them because they allow immediate application of new knowledge and skills, leading to better retention and understanding.”

Certificates are generally seen as valuable across most countries, serving as proof of skills. While some interviewees from Austria and Slovenia see certificates as important for students and valued by employers, the perspective varies slightly in France, where certificates are considered crucial in specific domains (like safety) but less so for general knowledge, or in Croatia, where more importance is placed on practical experience when it comes to employability.

“We do acknowledge certificates of proficiency, but they haven't been a decisive factor in our hiring process so far. While such certifications indicate a candidate’s commitment to learning, we place greater value on practical experience and the ability to apply knowledge in real-world scenarios.”

Conclusions

The interviews underscore a clear need for more comprehensive training and educational programs in emerging technologies like AI and robotics. While many industries recognize the importance of these innovations, especially larger companies, small and medium-sized enterprises (SMEs) often face barriers such as high costs and limited resources. Additionally, there is a shared consensus on the necessity of promoting circular economy practices, though more training and awareness are needed. Across all countries, the preference hands-on learning methods is evident, as it leads to better retention and application of skills. Certificates, though valued differently across regions, are generally seen as important, particularly when combined with practical experience.

5. Learning theories

Understanding how students learn is crucial for designing effective educational experiences, especially in fields like deep tech, robotics, AI, manufacturing, and sustainability, where hands-on learning is essential. Two prominent learning theories that inform modern didactic guidelines are Constructivism and the Cognitive Teaching Approach by Bloom & Krathwohl.

5.1 Constructivism

Constructivism views learning as the process by which learners come to construct their own understanding and knowledge of the world through experience and reflection on that experience. This learning theory posits that people are not passive recipients of knowledge but they actively build new ideas based on their current knowledge. Constructivism supports hands-on experimentation with emerging technologies in contexts relating to deep tech, robotics, AI, manufacturing, and sustainability to engage with students through direct interaction with such technologies through designing and prototyping real solutions in each of these areas. Emphasis is on problem-based learning through the solution of real-life problems that demand innovative, environmentally sound solutions, developing critical thinking via complex problem-solving skills. Collaborative projects consider the need for team orientation, including team-based assignments related to industrial aspects of manufacturing practice and sustainable development. The use of constructivist pedagogy also ensures the creation of a dynamic learning environment for the preparation of students as innovators and adopters in rapidly changing high-tech spheres of work, balancing economic and environmental interests.

5.2 Cognitivism teaching approach by Bloom & Krathwohl

Bloom's Taxonomy revised by David Krathwohl provides a hierarchical model that can be used to classify the different levels of cognitive learning, which include knowledge, comprehension, application, analysis, synthesis, and evaluation and can be applied by educators to develop curricula and assessments that are focused on developing higher-order thinking skills. It includes six categories: Remembering, Understanding, Applying, Analysing, Evaluating, and Creating. Implementing such a strategy in the teaching of core subjects like Deep tech, Robotics, AI, Manufacturing, and Sustainability, requires curriculum development that includes lesson formats that start with rudimentary knowledge to the most advanced evaluation and creation abilities, under guidance of each cognitive skill level. Different ways of evaluation are applied: varied quizzes, projects, presentations, and exams which require different levels of cognition: memory retrieval as well as application and synthesis of knowledge, which is especially important when it comes to creating sustainable and people-centric manufacturing approaches. Adaptive teaching methods adjust lessons to students differing cognitive capacities giving advanced students the chance to study more complex taxonomy levels. Skills development is prioritized with a focus on critical thinking creativity and an awareness of sustainable practices in addition to technical proficiency in robotics and AI. This helps students develop decision-making abilities that strike a balance between societal and environmental concerns and technological innovation preparing them for leadership roles. Teachers make sure that students acquire the broad skills necessary for success in industries that combine cutting-edge technologies with environmentally friendly manufacturing methods by employing Bloom and Krathwohls cognitive teaching approach.

6. Students with learning difficulties

6.1 Types of disabilities

Intellectual Disability: Refers to limitations in cognitive functioning and adaptive skills, such as communication, problem-solving, and daily life management. Common examples include Down syndrome or developmental delays.

Sensory Disability: Impacts one or more senses, such as vision or hearing. Examples include blindness, low vision, deafness, or hearing loss, affecting how a person perceives their environment.

Physical Disability: Affects a person’s mobility or motor functions. It may be caused by conditions like spinal cord injuries, cerebral palsy, muscular dystrophy, or amputations, making it difficult to perform physical tasks or move around.

Organic Disability: Relates to chronic conditions affecting internal organs, such as epilepsy, diabetes, or heart disease, where internal dysfunctions impact daily activities.

6.2 Other disorders.

Dyslexia: is a learning disability that affects reading. People with dyslexia have difficulty reading fluently and without errors. They may also struggle with reading comprehension, spelling, and writing. However, these challenges are not related to the individual's intelligence.

Dyscalculia: is a learning disability that affects mathematical abilities. People with dyscalculia may struggle with understanding numbers, performing basic arithmetic, and grasping math concepts. It can make tasks like telling time, handling money, or measuring difficult, but, in the case of dyslexia is not related to intelligence.

Attention Deficit-Hyperactivity Disorder (ADHD): is a neurodevelopmental disorder that affects focus, self-control, and impulse regulation. People with ADHD may have difficulty paying attention, staying organized, following instructions, or sitting still. The condition can affect both children and adults and is often characterized by symptoms of inattention, hyperactivity, and impulsiveness, but it varies in intensity from person to person.

6.3 Detection, intervention, and adaptation.

If a pupil shows signs of an impairment, the teacher should, if possible, identify the underlying impairment in order to adapt teaching for the pupil concerned.

When teaching, it is important that the teacher involves the classmates and creates an understanding of the need for consideration. In the case of intellectual, sensory or physical impairments, special consideration should be given to the pupil concerned by involving an appropriate educational specialist in lessons and supporting the pupil concerned in everyday school life. Access to the classroom and the teaching materials and concepts used should be designed to be barrier-free from the outset.

Pupils with dyscalculia can be helped, for example, by reading the teaching materials aloud together or by creating an open atmosphere for asking questions in the event of comprehension problems.

Pupils with ADHD can be helped by making lessons interactive and hands-on so that they are constantly stimulated cognitively. In order to help the pupils, organise their work content, it is advisable to carry out group work and increase the willingness of the teacher to aid.

7. Training Program

This training program is designed as part of a comprehensive guide that focuses on the integration of advanced technologies within the framework of human-centered manufacturing. Each session is meticulously crafted to cover critical topics such as Industry 5.0, circular economy principles, and the application of robotics, artificial intelligence, and deep tech in manufacturing processes. With a structured approach that combines theoretical knowledge and practical skills, the program aims to enhance participants' understanding of sustainable practices and innovative technologies.

Session No.	Title	Duration (hours)	Materials/Tools
1	Introduction and Overview	2	Manual & Background Materials: Overview of DRUMS and Deep Tech
2	Manufacturing	5	Manual & Background Materials: Manufacturing Techniques
			Manual & Tool: Advanced Manufacturing Processes
3	Circular Economy	6	Manual & Background Materials: Circular Economy Concepts
			Manual & Tool: Sustainable Manufacturing Practices
4	Artificial Intelligence	6	Manual & Background Materials: AI in Industry
			Manual & Tool: AI Applications for Sustainability
5	Robotics	6	Manual & Background Materials: Robotics in Manufacturing
			Manual & Tool: Automation Techniques
6	Deep Tech	5	Manual & Background Materials: Deep Tech Overview
			Manual & Tool: Integrating Advanced Technologies

8. Session plan and educational recommendations

8.1 Module 1: Introduction

Introduction
Proposed duration: 2 hours
Contents and objectives
This introductory module provides an essential foundation for understanding the DRUMS project. The focus will be on the principles of human-centered manufacturing, the importance of Industry 5.0, and the role of advanced technologies such as robotics, AI, and deep tech in shaping the future of manufacturing. It will also introduce sustainability practices and circular economy strategies as central themes within the framework of manufacturing innovation.
Possible Table of Contents (non exhaustive)
▪ Introduction to DRUMS and Industry 5.0. ▪ Overview of the DRUMS project: goals, scope, and impact. ▪ Principles of Industry 5.0: a shift from Industry 4.0 with a focus on human-centered and sustainable manufacturing. ▪ Key Technologies in Modern Manufacturing. ▪ Introduction to deep tech, AI, and robotics: defining the terms. ▪ Application of these technologies in the manufacturing process: real-world examples. ▪ Emerging trends and innovations in deep tech ▪ Sustainability and Circular Economy in Manufacturing. ▪ The role of circular economy principles in sustainable manufacturing. ▪ How technology supports sustainability: from energy efficiency to waste reduction. ▪ Case studies showcasing successful integration of sustainable practices in high-tech industries.
Possible objectives (non exhaustive) ▪ Understand the fundamental goals of Industry 5.0 and its human-centered approach to manufacturing. ▪ Define key terms related to deep tech, robotics, and AI in the context of manufacturing. ▪ Recognize the importance of sustainability in modern production processes.

- Identify how technological advancements can support the transition to a circular economy.

Potential learning outcomes (non exhaustive)

Potential knowledge (non exhaustive)

Learners will gain a foundational understanding of deep tech's role in Industry 5.0, including how AI, robotics, and sustainability practices reshape manufacturing

Potential skills (non exhaustive)

Learners will be able to discuss the benefits of these technologies and identify their applications within different manufacturing environments

Potential competences (non exhaustive)

Learners will be able to critically analyse the role of human-centered approaches in modern industrial practices, linking technological innovation to sustainability

Optional Learning Scenarios (suggestions, non exhaustive)

Not applicable

Optional Didactic recommendations and support (suggestions, non exhaustive)

Engagement with Real-World Examples

- **Recommendation:** Use practical case studies and examples from real-world applications to make abstract concepts like "Industry 5.0" and "deep tech" more relatable.
- **Support:** Provide case studies that showcase how companies are currently integrating human-centered approaches, deep tech, and sustainability into their manufacturing processes. Examples can include smart factories using AI and robotics or companies adopting circular economy models.
- **Example:** Share the story of a factory that implemented AI-driven predictive maintenance systems to reduce waste and downtime, ensuring human operators are still central to decision-making.

Use of Visuals and Interactive Media

- **Recommendation:** Leverage multimedia resources such as videos, infographics, and interactive presentations to explain complex topics like robotics and AI.

- **Support:** Create or curate high-quality videos that demonstrate the practical applications of these technologies in manufacturing. Include visual explanations of concepts like the circular economy and its connection to deep tech innovations. - **Example:** Use a video to show a smart manufacturing process where humans and robots collaborate to achieve greater efficiency and sustainability.
Optional exercises (suggestions, non exhaustive)
- **Quizzes:** A short quiz on key terms and principles related to Industry 5.0 and deep tech. - **Group Discussion:** Teams will discuss and present potential applications of deep tech and robotics in creating a sustainable manufacturing process. - Divide students into different groups. Each group is assigned a different industry (e.g., automotive, electronics, furniture manufacturing). Groups must research and present how human-centered approaches, such as worker wellbeing or enhanced ergonomics, could be integrated alongside advanced technologies (AI, robotics) in their assigned industry.
Possible Evaluation (suggestions, non exhaustive)
Not applicable
Optional Background Materials/Tools (suggestions, non exhaustive)
- **Project summary document:** Make a brief overview of the project's goals, key technologies, and expected outcomes. - **Industry 5.0 introduction video:** Use a video explaining the shift towards human-centered and sustainable manufacturing. - **Case study handouts on deep tech applications:** Use examples of real-world uses of AI and robotics in improving manufacturing efficiency and sustainability

8.2 Module 2: Manufacturing

Manufacturing
Proposed duration: 5 hours
Contents and objectives
This module provides a comprehensive presentation of manufacturing sector, types of manufacturing industries and processes, manufacturing systems and their workflow. It focuses also on quality control and its assurance in manufacturing sector. The course

enables the students to gain theoretical and practical knowledge on smart manufacturing technology and automation aspects according to Industry 4.0 principles
Possible Table of Contents (non exhaustive)
▪ Introduction to Manufacturing ▪ Types of Manufacturing Industries and processes ▪ Manufacturing Systems and Workflow ▪ Quality Control and Assurance ▪ Technology and Automation
Possible objectives (non exhaustive)
▪ Provide an in-depth understanding of the manufacturing sector ▪ Understanding the types of manufacturing industries and processes ▪ Gain in-depth knowledge on manufacturing systems and workflow ▪ Provide the best practice in quality control and its assurance ▪ Discover best practice case studies on quality improvement ▪ Understand the role of automation and robotics in manufacturing ▪ Discover the significance of Industry 4.0 and smart manufacturing technology
Potential learning outcomes (non exhaustive)
Potential knowledge (non exhaustive)
▪ Understand the manufacturing sector and its importance ▪ Understand the types of manufacturing industries and processes ▪ Gain in-depth knowledge on manufacturing systems and workflow ▪ Discover best practices in quality control and best practice case studies on quality improvement ▪ Understand the role of automation and robotics in manufacturing ▪ Recognize the significance of Industry 4.0 and smart manufacturing technology
Potential skills (non exhaustive)
▪ Problem solving skills in the manufacturing sector ▪ Quality control skills ▪ Digital skills

Potential competences (non exhaustive)
▪ Distinguish among the types of manufacturing industries and processes ▪ Analyse different manufacturing techniques ▪ Analyse the energy efficiency and waste reduction in the manufacturing sector ▪ Collaborate on planning and design of manufacturing system with adequate workflow ▪ Implement quality control in manufacturing sector ▪ Contribute to discussions on the role of automation and robotics in manufacturing sector ▪ Thoughtful use of smart manufacturing technology in accordance with Industry 4.0 guidelines
Optional Learning Scenarios (suggestions, non exhaustive)
Case Study Analysis: analyse different case studies of production companies or industries that have successfully implemented automation and robotics solutions into their production lines. These case studies could cover a wide range of different production fields, where smart manufacturing industry could be implemented in accordance to industry 4.0. **Field Visits:** organize field visits to local production companies or industries that have successfully improved their manufacturing process by increasing the level of automation and robotics to boost productivity. This could include visits to industrial R&D centres, manufacturing lines that increased their level of productivity.
Optional Didactic recommendations and support (suggestions, non exhaustive)
Integrate Case-Based Learning: ▪ **Recommendation:** use case studies of manufacturing companies that have successfully implemented automation, robotics, and Industry 5.0 technologies. ▪ **Support:** provide students with background material on specific manufacturing industries where automation, robotics, and Industry 5.0 concepts are applied, and encourage them to analyse how these strategies were implemented and their benefits for better productivity. ▪ **Example:** use cases like AUDI, VW etc. transition to increase their productivity of car manufacturing or similar manufacturing companies that invested into automation, robotics and industry 4.0 solutions. **Encourage Active Participation and Group Collaboration:** ▪ **Recommendation:** structure group activities were students collaborate on problem-solving projects such as designing manufacturing lines with improved automation solutions, robot’s integration and implementation of industry 4.0 solutions.

- **Support:** provide clear guidelines and expectations for group work, as well as tools (like Siemens Plant simulation Software tool, robotic simulators...) that will aid them in their project execution.
- **Example:** assign students to work in teams to create an improved manufacturing line for a fictional company, using real-world data on production workflow and settings, and realistic production times.

Use Practical Labs for Skills Development:

- **Recommendation:** include practical labs where students can apply automation, robotics, and Industry 4.0 concepts in hands-on environments, such as designing manufacturing line using Siemens plant simulation tools to assess and evaluate the production times of specific products or manufacturing processes.
- **Support:** provide access to plant simulation, robot simulation and similar software, as well as to automation and robotics equipment checklists, critical sensors lists, production charts, etc.
- **Example:** a lab exercise where students evaluate the productivity of a production line while producing given parts (e.g., car lights) using Siemens software, and then redesign the production line in order to increase the productivity.

Link Theory to Emerging Technologies:

- **Recommendation:** show students how manufacturing concepts are enhanced by using emerging technologies like robotics, artificial intelligence (AI), and deep tech. Encourage them to explore how these technologies can optimize manufacturing process in a way to further boost recycling, waste management, and increase productivity.
- **Support:** provide resources on the latest developments in technology and its role in manufacturing strategies. Include guest lectures like for example industry experts or showcase videos and reports on how I4.0, automation, AI and robotics are used in smart factories.
- **Example:** demonstrating how industry 4.0 can improve manufacturing process, improve predictive maintenance and increase productivity of production machines taking into consideration also sustainability practices in production processes (e.g., green manufacturing).

Foster Critical Thinking and Reflection:

- **Recommendation**: encourage students to critically analyse the benefits and challenges of applying automation and robotic solutions into the manufacturing sector through discussions and reflective exercises. Students should consider real-world limitations, such as technical and safety challenges, market readiness, and technology adoption barriers.

- **Support:** offer discussion prompts and reflective questions in classroom debates or with exercises where students reflect on the feasibility of implementing automation and robotics solutions in different manufacturing industries.
- **Example:** a class discussion on the manufacturing challenges on how to implement automation, robotics and I4.0 solutions to foster a smooth transition from low technological readiness of manufacturing lines towards more modern, smarter and productive manufacturing.

Provide Continuous Feedback and Evaluation:

- **Recommendation:** throughout the module, give students timely feedback on their work, especially on their understanding and application of automation, robotics and industry 4.0 solutions into manufacturing world in assignments and projects.
- **Support:** use rubrics for evaluating projects, labs, and group activities based on criteria like adoption of automation solutions, robotics, AI, deep tech and alignment with industry 4.0 standards. Schedule one-on-one meetings or provide detailed comments to help students improve.
- **Example:** offering personalized feedback on students' manufacturing line modernization, highlighting strengths and areas for improvement in terms of adopting automation, robotics, AI and deep-tech solutions to improve productivity.

Optional exercises (suggestions, non exhaustive)

Exercise 1. Improved manufacturing line design:

- Students can work in groups on different exercises in the manufacturing sector, namely on following topics: lower material and energy consumption, increased productivity, adaptation of Sustainable Manufacturing Practices and Techniques (zero-defect).
- Students will then evaluate the benefits of their approaches using plant simulation tools, robotics simulation or any other similar software, and discuss the challenges and benefits.

Exercise 2. Increased productivity assurance:

- Teams develop a concept of a smart manufacturing line for a process by proposing different automation and robotics solutions (increasing the level of automation and number of robots) to boost productivity.
- Teams discuss the challenges and benefits of prosed solutions in case of applying it to the real manufacturing sector.

Exercise 3. Quality assurance:

- Students design a quality assurance system for monitoring the produced part quality for a given manufacturing line.

- Present their proposed quality system with a focus on better traceability and quality control of every produced part.

Possible evaluation (suggestions, non exhaustive)

- **Quizzes:** assess knowledge on this module through quizzes.
- **Final Project:** students propose and develop a concept of a smart manufacturing line with increased level of automation, proposing of adequate number of robots for given line, and they can introduce/justify different solutions like AI, ML, IoT, Deep Teach to create a smart manufacturing line in accordance with Industry 4.0 guidelines by preparing a final report or presentation.
- **Participation:** engagement in practical labs, field visits and case study discussions among the group.

Optional Background Materials/Tools (suggestions, non exhaustive)

- **Case Studies:** practical real-world examples on successfully improved/digitalized manufacturing line for a part production with increased productivity by improving the level of automation, integration of robotics and adopting certain smart manufacturing technologies.
- **Comparison with conventional production line.**

8.3 Module 3: Circular Economy

Circular Economy

Proposed duration: 6 hours

Contents and objectives

This module provides an in-depth exploration of circular economy principles, regulations, strategies, design, and business models. It focuses on how industries can transition towards circularity by optimizing resource use, extending product lifecycles, and reducing environmental impacts. The course equips students with the skills to implement circular economy concepts in practical, industry-relevant scenarios.

Possible Table of Contents (non exhaustive)

- Definitions and Introduction: Why Circular Economy is needed
- Foundations: Short Overview of Regulatory Frameworks and standards, Life Cycle Thinking and Environmental Impact Assessments, Critical Raw Materials
- Circular Economy Strategies: From predictive maintenance to recycling

▪ Circular Design: Guidelines and product development process for sustainability ▪ Circular Business Models: Development of business models for slowing, narrowing, intensifying and improving product life cycles
Possible objectives (non exhaustive)
▪ Understand the Need for Circular Economy (CE) ▪ Learn Key Regulations and Standards ▪ Apply Life Cycle Thinking and Life Cycle Assessment Screening (LCA-Screening) ▪ Explore Circular Economy Strategies ▪ Understand Eco-design Principles ▪ Analyse Circular Business Models ▪ Link Circular Economy to Emerging Technologies
Potential learning outcomes (non exhaustive)
Potential knowledge (non exhaustive)
▪ Understand the resource challenges driving the need for circular economy (CE) strategies, including global resource depletion. ▪ Comprehend key regulations like Eco-design Directive, ISO standards, and extended producer responsibility frameworks that govern CE practices. ▪ Grasp the role of Life Cycle Assessment (LCA) and Life Cycle Thinking in evaluating environmental impacts. ▪ Recognize the significance of critical raw materials in the context of circularity. ▪ Familiarize with circular economy strategies, including material use, refurbishing, and predictive maintenance, and how these link with technologies like robotics, AI, and deep tech. ▪ Understand principles of Eco-design and how modularity and circular design influence the product development process. ▪ Learn about circular business models and their application in sharing, leasing, reverse logistics, and supply chain management.
Potential skills (non exhaustive)
▪ Apply Life Cycle Thinking and Life-Cycle-Assessment Screening to assess the sustainability of products and processes on a basic level.

- Use predictive maintenance and refurbishing strategies to find ideas for extending the product life and improve resource efficiency.
- Implement basic Eco-design principles in product development with a focus on modularity, easy disassembly, and recyclability.
- Develop circular business models such as leasing, pay-per-use, software as a service, and reverse logistics systems.
- Analyse and create strategies for reverse logistics and circular supply chain management.

Potential competences (non exhaustive)

- Find the most important life cycle phases and find improvements for circular processes and products.
- Collaborate in designing sustainable product life cycles and applying circular economy strategies.
- Contribute to discussions on resource management and regulatory compliance.
- Implement circular business models that align with industry standards and regulatory requirements.
- Thoughtful use of critical raw materials
- Optimization of end-of-life product strategies such as automatic sorting and recycling.

Optional Learning Scenarios (suggestions, non exhaustive)

- **Case Study Analysis**: Analyse in principle real-world case studies of companies or industries that have successfully implemented circular economy practices. These case studies could cover a wide range of sectors, from electronics recycling to sustainable construction.
- **Field Visits**: Organize field visits to local companies or industries that have successfully implemented circular economy practices. This could include visits to recycling centers, remanufacturing plants, or businesses with sustainable supply chains.
- **Workshops on Circular Design and Prototyping**: Conduct hands-on design workshops where students create prototypes of products designed according to circular economy principles, such as modularity, biodegradable materials, or recyclability. Students can experiment with simplified Life Cycle Assessment screening (LCA-screening) tools, and circular business model tools, to develop circular products and components, and a suitable circular business model.
- **Circular Economy Hackathon or Innovation Challenge**: Organize a hackathon where students work in teams to propose innovative circular economy solutions for real-world

problems. Teams could be tasked with developing a new business model, product design, or supply chain process that incorporates circular principles.

Optional Didactic recommendations and support (suggestions, non exhaustive)

Integrate Case-Based Learning:

- **Recommendation**: Use case studies of companies that have successfully adopted circular economy strategies, such as businesses implementing leasing models, reverse logistics, or circular product design.
- **Support**: Provide students with background material on specific industries (e.g., electronics, automotive, textiles) where circular economy concepts are applied, and encourage them to analyse how these strategies were implemented and their benefits.
- **Example**: Showcases like **Philips**' transition to a circular business model for lighting systems (pay-per-lux) or **Patagonia**'s efforts in creating circular textiles.

Encourage Active Participation and Group Collaboration:

- **Recommendation**: Structure group activities where students collaborate on projects such as designing circular products, developing circular business models, or planning reverse logistics systems.
- **Support**: Provide clear guidelines and expectations for group work, as well as tools (like LCA-screening software or circular business model design tools) that will aid them in their project execution.
- **Example**: Assign students to work in teams to create a circular business model for a fictional company, using real-world data on material lifecycles and customer behaviour.

Use Practical Labs for Skills Development:

- **Recommendation**: Include practical labs where students can apply circular economy concepts in hands-on environments, such as designing modular products or using LCA-screening tools to assess the environmental impact of specific products or processes.
- **Support**: Provide access to LCA-screening and similar software, as well as to materials like circularity checklists, critical raw material lists, recyclability charts, etc.
- **Example**: A lab exercise where students evaluate the environmental impact of a product (e.g., a smartphone) using LCA-screening software, and then redesign the product using circular design principles (e.g., reusability, modularity, recyclability).

Link Theory to Emerging Technologies:

- **Recommendation**: Show students how circular economy concepts are enhanced by emerging technologies like robotics, artificial intelligence (AI), and deep tech. Encourage them to explore how these technologies can optimize processes like recycling, waste management, and product lifecycle monitoring.

- **Support**: Provide resources on the latest developments in technology and its role in circular economy strategies. Include guest lectures from industry experts or showcase videos and reports on how AI and robotics are used in smart recycling plants.
- **Example**: Demonstrating how AI can improve sorting processes in recycling centers or how predictive maintenance enabled by IoT can extend the lifespan of industrial machinery.

Foster Critical Thinking and Reflection:

- **Recommendation**: Encourage students to critically analyse the benefits and challenges of circular economy models through discussions and reflective exercises. Students should consider real-world limitations, such as regulatory challenges, market readiness, and technology adoption barriers.
- **Support**: Offer discussion prompts and reflective questions throughout the module. Facilitate classroom debates or writing exercises where students reflect on the feasibility of implementing circular economy strategies in different industries.
- **Example**: A class discussion on the challenges of transitioning to circular models in emerging markets or industries with low technological readiness.

Provide Continuous Feedback and Evaluation:

- **Recommendation**: Throughout the module, give students timely feedback on their work, especially on their understanding and application of circular economy principles in assignments and projects.
- **Support**: Use rubrics for evaluating projects, labs, and group activities based on criteria like innovation, feasibility, sustainability, and alignment with industry standards. Schedule one-on-one meetings or provide detailed comments to help students improve.
- **Example**: Offering personalized feedback on students' circular business models, highlighting strengths and areas for improvement in terms of sustainability, regulatory alignment, and market feasibility.

Optional exercises (suggestions, non exhaustive)

Exercise 1: Design a Circular Product

Objectives:

- Design a product following circular economy principles (reuse, repair, refurbish, remanufacture, recycle) and evaluate the environmental benefits.

Instructions:

- Form Groups and choose a product category (e.g., electronics, furniture, fashion).
- Apply circular principles (e.g., modularity, easy disassembly, durable materials) to ensure the product can be reused, repaired, or recycled.

- Evaluate the environmental performance with Life Cycle Assessment-screening tools of your circular design to compare the environmental impacts with a conventional product.
- Present key features and LCA-Screening findings

Group Reflection:

- Discuss which design challenges were faced, and what were the most significant environmental benefits?

Exercise 2: Design a circular Business Model

Objectives:

- Develop a circular business model (use-oriented or result-oriented) that maximizes resource efficiency and try to understand the challenges and opportunities in adopting circular business models.

Instructions:

- Form teams and select a product/service category (e.g., electronics, clothing, office equipment).
- Use the Business Model Canvas to create a circular business model that includes a use-oriented or result-oriented service level.
- Discuss the challenges of implementing your model (e.g., infrastructure, consumer behaviour, costs, revenue streams).
- Present the business model and the revenue streams, as well as the environmental benefits.

Group Reflection:

- Discuss which challenges were faced in designing the business model and what advantages and barriers exist for implementing the proposed solution.

Possible evaluation (suggestions, non exhaustive)

- **Quizzes:** Assess knowledge on regulations, circular design principles, and circular business models through quizzes.
- **Final Project:** Students propose and develop a concept for a circular product, a reverse logistic system and a circular business model with a report and presentation.
- **Participation:** Engagement in practical labs, hackathons, workshops, field visits and case study discussions.

Optional Background Materials/Tools (suggestions, non exhaustive)

- **Eco-design Guidelines:** Materials on modular design, connection techniques, critical raw materials, and product development processes.

- **Software:** Software and guides for conducting Life Cycle Assessments Screenings, Product Carbon Footprints and Circular Business Models.
- **Case Studies:** Real-world examples of successful circular business models, including leasing, reverse logistics, and product life extension strategies.

8.4 Module 4: Artificial Intelligence

Artificial Intelligence
Proposed duration: 6 hours
Contents and objectives
This module explores the different types of Artificial intelligence with a focus on machine learning and its subcategories. The course aims to prepare the students to understand the basics of AI, the importance of the data used to train AI models as well as to enable the students to identify potential use cases for the application of AI in their work life.
Possible Table of Contents (non exhaustive)
▪ Introduction to Artificial Intelligence ▪ Machine Learning and Deep Learning: Basic Concepts ▪ The Role of Data in AI ▪ Benefits and risks of AI ▪ Ethics of AI ▪ AI in Manufacturing: Practical Consideration
Possible objectives (non exhaustive)
▪ Form an understanding of what AI is and what types of AI exist ▪ Form an understanding of machine learning and deep learning on a basic level ▪ Being able to understand the importance of data for machine learning applications and how the results depend on the data ▪ Being able to assess the main benefits and risks of AI on a general level as well as the ability to apply this knowledge towards the assessment of specific applications ▪ Form an understanding of the ethics of AI with a focus on specific challenges and applications in manufacturing
Potential learning outcomes (non exhaustive)

Potential knowledge (non exhaustive)
▪ Understand what AI is and differentiate between types of AI ▪ Understanding of Machine Learning and Deep Learning ▪ Understand the importance of data in machine learning and how the quality of data affects outcomes.
Potential skills (non exhaustive)
▪ Being able to identify possible use cases for AI applications in their own work life. ▪ Ability to identify relevant aspects of domain knowledge for the development of an AI System ▪ Be able to assess data quality and understand the process of data pre-processing, including feature selection and engineering. ▪ Be able to critically assess the main benefits and risks of AI in different sectors, especially in manufacturing
Potential competences (non exhaustive)
▪ Develop the ability to apply basic AI tools to solve predefined problems within a familiar and structured environment ▪ Develop the competence to apply ethical reasoning when developing or assessing AI technologies, especially in manufacturing environments.
Optional Learning Scenarios (suggestions, non exhaustive)
▪ **Introduction to AI Concepts:** Give a brief classroom lecture on the basics AI and machine learning. The main takeaways from the students is that they are able to describe the differences between weak AI and strong AI as well as the concepts supervised learning, unsupervised learning and reinforcement learning. Give clear and easy to understand examples for each concept. ▪ **Machine Learning in Practice:** Hands on workshop where students experiment with basic and pre-programmed machine learning algorithms) using sample datasets in order to help students understand how machine learning methods work. ▪ **Data's Role in Machine Learning:** Group project where students evaluate different datasets and pre-process them in order to understand how data quality impacts machine learning results. ▪ **Assessing AI Risks and Benefits:** Debate session where students are divided into teams to argue the risks vs. benefits of AI in different fields (e.g., healthcare, autonomous

vehicles, production) in order to develop critical thinking about the potential impacts of AI.

- **Ethics of AI in Manufacturing:** Conduction of a case study analysis where students examine a real-world ethical dilemma in AI-driven manufacturing (e.g., worker displacement, privacy concerns) in order to facilitate ethical awareness and decision-making.

Optional Didactic recommendations and support (suggestions, non exhaustive)

Blended Learning Approaches

- **Recommendation:** Combine traditional in-person lectures with online modules, self-paced learning resources, and interactive tools such as quizzes.
- **Support:** Provide students with access to an online learning platform where they can find further learning materials.
- **Example:** After an introductory in-class lecture on machine learning, assign an online module where students watch short tutorial videos on implementing machine learning algorithms. Students complete a quiz afterward to reinforce key concepts and discuss the results in a group

Hands-On Projects

- **Recommendation:** Incorporate practical, hands-on coding projects using easy to use programming building blocks or data analysis exercises early in the course to complement theoretical understanding with practical application.
- **Support:** Offer step-by-step guidance during initial exercises and create space for troubleshooting sessions where students can ask questions and get feedback on their work. Provide code easy to use software that enables the students to understand the concepts without needed to program source code themselves to reduce the initial barrier.
- **Example:** During a session on data pre-processing, give students a raw dataset and guide them through the process of cleaning and normalizing it using Python or Excel. Provide a template that outlines the steps of the process, and during lab sessions

Group Work and Peer Learning

- **Recommendation:** Encourage collaborative learning by having students work in groups to solve problems, conduct research, or critique each other’s work.
- **Support:** Assign groups intentionally to ensure diversity in skill levels and perspectives. Monitor group progress and provide clear roles for each team member to ensure engagement from all participants.
- **Example:** For a group project on the risks and benefits of AI, assign each group a different industry (e.g., healthcare, transportation, manufacturing). Each group must

research and present their findings to the class, allowing for peer feedback sessions where other groups provide suggestions or counterarguments.

Ethics Discussions and Debates

- **Recommendation:** Incorporate ethics as a central theme in AI discussions by using preparing AI based use cases that can be used as a basis for debates.
- **Support:** Keep a sheet with some arguments for the use of prohibition of AI for the selected use cases at hand to facilitate the debate. Ensure equal participation amongst the students.
- **Example:** Set up a debate where one group defends the use of facial recognition in public spaces for security purposes, while another group argues against it on privacy grounds. Equip students with ethical frameworks and background materials to help them structure their arguments. After the debate, summarize the main ethical considerations and discuss how they can apply to other AI scenarios.

Optional exercises (suggestions, non exhaustive)

Exercise 1: Influence of Data for AI models

Objectives: Collect data for a machine learning application and discuss the training results based on a given use-case

Instructions:

- Begin with a short introduction regarding the tools used to collect the dataset and train the machine learning model
- Present the students with a use case for which they have to collect the data
- Split the students into small groups
- Have the students collect the data and train the AI model using the provided framework

Group Reflection:

- Discuss the encountered challenges and have the students describe what they observed when using the machine learning model for inference.
- Discuss how certain unexpected and expected behaviours of the machine learning model can be explained and how changes have to be addressed

Exercise 2: AI Classification

Objectives: Classify whether or not different types of applications are using AI and if so which to identify which type of AI

Instructions:

- Give a presentation on how specific AI categories work and what they are usually used for.

- Provide the students with examples of applications used in day to day life and have them identify whether or not AI models are used in those applications
- Have the students take notes on how they identified the use of AI and discuss the results as a group

Group Reflection:

- Discuss why the students think that the applications do or do not include AI models.
- Facilitate the discussion by giving the students hints if necessary

Exercise 3: Data Pre-processing Assignment

Objectives: Understanding what type of data are important regarding a given use case in a specific dataset

Instructions:

- Begin with a brief presentation on feature engineering
- Present the students with a use case and a specific dataset for the given use case that contains different types of data that can be used to solve a machine learning task.
- Let the students decide on which data in the overall dataset is relevant for the given use case

Group Reflection:

- Discuss the results in a group and have the students explain their results.

Exercise 4: AI benefit and risk assessment

Objectives: Enable the students to identify the risks and benefits for a given AI application

Instructions:

- Give a short presentation of the benefits and risks of AI using a specific application as an example
- Present the students with another use case, preferably on with a focus on their day to day work life.
- Have the students create a list of benefits and risks in small groups and have them discuss whether or not the benefits outweigh the risks for the given application.

Group Reflection:

- Discuss the results of the groups and compare their results.
- The group discussion gives students the ability to better assess the advantages and disadvantages of AI in relation to specific use cases

Exercise 5: Ethical Analysis in Manufacturing

Objectives: Students are able to assess the ethical justifiability of AI use cases in manufacturing

Instructions:

- Give a presentation on the ethics of AI with a focus on how AI can be used to improve work for humans rather than replace them
- Provide a written use case regarding the introduction of AI in manufacturing to the students includes positive and negative statements from workers regarding the introduction of said AI system.
- Have the students write a short essay in which they describe whether or not they think the introduction is conducted in a responsible way.
- Have the students take notes on how they think the introduction can be improved.

Group Reflection:

- Discuss the results in a group and have the students debate based on their written essays

Possible evaluation (suggestions, non exhaustive)

- **Quizzes:** Short assessments on the types of Artificial Intelligence and their applications.
- **Practical Lab Assessments:** Graded performance based on a given machine learning problem with specific dataset.
- **Final Project:** Design and implementation of a small machine learning project with a corresponding documentation
- **Participation:** Engagement in discussions, practical labs, and group work.

Optional Background Materials/Tools (suggestions, non exhaustive)

- **Hardware:** Computer with internet access and sufficient specifications for the use of machine learning
- **Software:** Software and guides for the low-threshold implementation of machine learning models

7.5 Module 5: Robotics

Robotics
Proposed duration: 6 hours
Contents and objectives

This module explores the applications of robotics in manufacturing sector. Topics covered include robotic assembly, disassembly, human-robot interaction, and the role of sensors, cameras, and grippers in modern robotic systems. The course aims to prepare students to understand and work with industrial robots, with a focus on precision, efficiency, and future trends.

Possible Table of Contents (non exhaustive)

- Introduction to industrial Robotics.
- Robotic Assembly, Disassembly and Recycling Applications.
- Human- Robot Interaction and Cobots.
- Mechatronics and Peripherals: Sensors, Cameras, and Grippers.
- Trends and Future of Robotics in Industry.

Possible objectives (non exhaustive)

- Understand the Basic of Industrial Robotics.
- Learn the basics of Robotic Assembly and Disassembly Processes.
- Explore Human-Robot Interaction.
- Grasp the Fundamental of Mechatronics in Robotics.
- Explore Emerging Trends in Robotics and Automation.

Potential learning outcomes (non exhaustive)

Potential knowledge (non exhaustive)

- Understand basic principles of how robots are used in assembly and disassembly in industries like electronics, furniture, and automotive manufacturing.
- Know the main applications of robotics in tasks such as assembling products and recovering materials for recycling.
- Recognize key hardware components in robotics, including sensors, cameras, and grippers.

Potential skills (non exhaustive)

- Apply basic robotic systems in industrial tasks, such as simple assembly and disassembly processes.
- Operate and configure simple robotic tools, like sensors and cameras, for basic manufacturing tasks.

- Work safely with collaborative robots (cobots) in shared spaces, following safety procedures.

Potential competences (non exhaustive)

- Assist in setting up robotic systems to improve basic industrial processes.
- Adapt robots to perform specific tasks with guidance, focusing on safety and efficiency.
- Contribute to evaluating robotic processes in terms of efficiency and sustainability under supervision.

Optional Learning Scenarios (suggestions, non exhaustive)

- **Case Studies:** Real-world examples of robots in electronics and automotive manufacturing.
- **Practical Labs**: Hands-on sessions where students work with robotic arms, grippers, and sensors.
- **Group Projects**: Designing a robotic assembly line for a specific industry.
- **Simulations**: Use of virtual environments to simulate robotic operations in disassembly and recycling.

Optional Didactic recommendations and support (suggestions, non exhaustive)

Use of Practical, Real-World Examples

- **Recommendation:** Use relatable, real-world examples to explain the principles and applications of robotics.
- **Support**: Introduce scenarios from manufacturing where robots perform tasks like assembly, welding, and packaging. Relate robotic applications to everyday technologies such as robotic arms used in car manufacturing or food processing.
- **Example:** Show a video of a robotic arm assembling a car part, followed by a class discussion on how automation improves precision and reduces human error.

Group Work and Peer Learning

- **Recommendation:** Promote collaborative learning through group exercises and peer-to-peer feedback.
- **Support:** Divide students into small groups and assign them collaborative robotic tasks, such as designing a robotic process for a hypothetical manufacturing line. Encourage students to share their solutions with the class, allowing for feedback and suggestions from peers.

- **Example:** Assign groups to configure a robot to assemble different components of a product. Each group presents their approach, and other groups critique and offer improvement ideas.

Optional exercises (suggestions, non exhaustive)

Exercise 1: Robotic Assembly Basics

Objectives: To understand the basics of robotic operation and configuration by completing a simple assembly task.

Instructions:

- Begin with a brief introduction on robotic systems in manufacturing.
- Present a robotic assembly task where students program a robot to assemble a simple product, such as positioning components on a circuit board.
- Perform the task and analyse the robots performance in terms of speed, accuracy, and efficiency.

Group Reflection:

- Discuss the challenges encountered and how to improve task efficiency.
- By following this structure, students will gain hands-on experience with robotics and better understand its role in modern manufacturing.

Exercise 2: Human-Robot Collaboration and Safety

Objective: To explore human-robot collaboration and understand the safety measures required in shared work environments.

Instructions:

- Start with an introduction to collaborative robots (cobots) and their role in working alongside humans in industrial settings.
- Set up a scenario where students must program a cobot to assist in a task, such as packaging small items into boxes, while a human performs complementary tasks like quality control.
- Ensure safety protocols are integrated into the task, including programming the cobot to slow down or stop when a human enters its workspace.

Group Reflection:

- Discuss how human-robot collaboration improves efficiency and safety, and identify any potential challenges or improvements in the workflow.
- This exercise will help students understand the importance of safety and efficiency in human-robot collaboration, giving them practical insight into its applications in modern industries.

Possible evaluation (suggestions, non exhaustive)
▪ **Quizzes:** Short assessments on the types of robotic hardware and their applications. ▪ **Practical Lab Assessments:** Graded performance on assembly/disassembly tasks using robotic systems. ▪ **Final Project:** Designing and simulating a robotic assembly/disassembly line with a written report. ▪ **Participation:** Engagement in discussions, practical labs, and group work
Optional Background Materials/Tools (suggestions, non exhaustive)
▪ **Robotics system setup guide:** Guides providing detailed instructions on how to install and configure robotic systems, covering aspects such as hardware assembly, software installation, and initial calibration for optimal performance in manufacturing environments. ▪ **Safety procedures for human/robot collaboration:** Outlines essential safety protocols to ensure safe interaction between humans and robots in shared workspaces. It includes guidelines for minimizing risks, defining safe zones, and using protective measures to prevent accidents. ▪ **Robotic hardware manuals (sensors, cameras, grippers):** Manuals providing technical documentation and specifications for the various hardware components of a robot, such as sensors, cameras, and grippers. They explain how each component functions, how to install and maintain them, and how they interact with the rest of the robotic system. ▪ **Evaluation checklists for robotic performance:** These checklists serve as tools to assess and monitor the performance of robotic systems. They help in evaluating factors like accuracy, speed, and efficiency of operations, ensuring that the robot meets the desired performance standards.

8.6 Module 6: Deep Tech

Deep Tech
Proposed duration: 5 hours
Contents and objectives
This learning module offers a comprehensive introduction to Deep Tech while addressing the potential of emerging technologies for accelerating the transition towards a circular economy.

Students will be provided with both theorical knowledge and practical insights, enabling them to dive into the applications of Deep Tech to the manufacturing industry as well as to gain understanding of the importance of Deep Tech both within the industry 5.0 context and the transition towards a circular economy.
Possible Table of Contents (non exhaustive)
▪ Introduction to the deep tech ▪ Foundational Technologies within Deep Tech ▪ Deep tech for sustainability
Possible objectives (non exhaustive)
▪ Introduce Deep Tech and its key enabling technologies. ▪ Explain the role of Deep Tech within the transition towards a circular economy. ▪ Provide students with an insight into Deep Tech applications through interactive exercises. ▪ Showcase best practice examples of start-ups within the Deep Tech ecosystem.
Potential learning outcomes (non exhaustive)
Potential knowledge (non exhaustive)
▪ Understand the foundational principles of Deep Tech technologies. ▪ Understand the Deep Tech concept and Deep Tech fields, notably advanced materials; virtual and augmented reality; and digital twins. ▪ Gain insight into the applications and implications of these technologies in the context of the manufacturing sector. ▪ Discover the role of Deep Tech in the transition towards a circular economy, including the application of circular business models.
Potential skills (non exhaustive)
▪ Problem solving skills ▪ Analytical skills ▪ Entrepreneurial skills ▪ Green skills ▪ Digital skills
Potential competences (non exhaustive)

- Problem-solving competencies
- Innovation competencies
- Strategic thinking

Optional Learning Scenarios (suggestions, non exhaustive)

- **Challenge-based exercise on circular business models applied to Deep Tech:** students address open challenges on Deep Tech by applying circular business models.
- **Pitching session on circular business models:** students will pitch their solutions and provide feedback to other groups, fostering peer-to-peer learning.
- **Interactive session on Deep Tech technologies:** students will explore key Deep Tech technologies by interacting with the EIT Deep Tech Talent Initiative's Radar[1], a web-based tool for visualising emerging technologies.

Optional Didactic recommendations and support (suggestions, non exhaustive)

Integration of the challenge-based learning approach:

- **Recommendation:** integrate challenge-based exercises with a view to connect the theoretical knowledge with its practical applications and promote peer-to-peer learning. Challenge-based exercises also improve the problem-solving, entrepreneurial and analytical skills of the students.
- **Support:** real-life examples of Deep Tech challenges for students.
- **Example**: challenge-based exercise on circular business models (see exercise 1 of module 6).

Applying interactive learning for exploring emerging technologies:

- **Recommendation**: use an interactive web-based tool for allowing students to get familiar with emerging technologies. The benefits of interactive learning include enhanced retention, improved critical thinking and higher engagement and motivation.
- **Support:** will be provided by an emerging technologies interactive platform, such as the EIT Deep Tech Talent Initiative's Radar, which allow users to explore and visualize emerging technologies.
- **Example:** Deep tech use cases identification (see exercise 2 of module 6).

Optional exercises (suggestions, non exhaustive)

Exercise 1. Challenge-based exercise on circular business models:

Objective: engage students in the application of circular business models to Deep Tech challenges. The challenge-based approach of the exercise will allow students to gain entrepreneurial skills while working in teams to address real-life problems faced by companies.

Instructions:

- Presentation of the Deep Tech challenges.
- The students, divided into groups, will define solutions that address one of the challenges. Students will apply circular business models for formulating the solutions, which will be showcased on a business model canvas.

Group reflection:

- Each group will pitch their solution to all participants, supported by the circular model canvas.
- Students will provide peer-to-peer feedback.

Exercise 2. Deep tech use cases identification:

Objective: familiarise students with emerging technologies and the corresponding use cases by applying interactive learning methods.

Instructions:

- Presentation of the exercise and the emerging technologies interactive web-based tool.
- Students will navigate the tool individually.
- Divided into groups, students will be assigned an emerging technology and will be asked to identify and describe three use cases.

Group reflection:

- Each group will present the use cases identified.
- After each presentation, all students will be encouraged to provide feedback and suggest further use cases corresponding to the emerging technology presented.

Possible evaluation (suggestions, non exhaustive)

- **Quizzes:** quiz covering the module content.
- **Challenge-based exercises:** evaluation of the business model canvas and pitch.

Optional Background Materials/Tools (suggestions, non exhaustive)

- **Circular business model canvas**
- **Deep Tech challenges**[4]
- **The EIT Deep Tech Talent Initiative's Tech Radar**[5]

Glossary

Algorithm

An algorithm consists of a set of instructions or steps used to solve a problem (e.g., it does not include the data). The algorithm can be abstract and implemented in different programming languages and software libraries.

Artificial Intelligence

An AI system is a machine-based system that is capable of influencing the environment by producing an output (predictions, recommendations or decisions) for a given set of objectives. It uses machine and/or human-based data and inputs to (i) perceive real and/or virtual environments; (ii) abstract these perceptions into models through analysis in an automated manner (e.g., with machine learning), or manually; and (iii) use model inference to formulate options for outcomes. AI systems are designed to operate with varying levels of autonomy.

Augmented Reality

A system that supplements the real world with virtual (computer generated) objects that appear to coexist in the same space as the real world. An AR system [will] have the following properties: combines real and virtual objects in a real environment; runs interactively, and in real timal 2001, 34)

Automatic/Automation/Automated

Pertaining to a process or system that, under specified conditions, functions without human intervention.

Circular economy

A systems solution framework that tackles global challenges like climate change, biodiversity loss, waste, and pollution. It is based on three principles, driven by design: eliminate waste and pollution, circulate products and materials (at their highest value), and regenerate nature.

It is underpinned by a transition to renewable energy and materials. Transitioning to a circular economy entails decoupling economic activity from the consumption of finite resources.

Deep tech

Deep tech innovations are cutting-edge technological solutions combining fields of science and engineering in the physical, biological and digital spheres.

Eco-design

The integration of environmental aspects into the product development process, by balancing ecological and economic requirements. Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle.

Human-centric AI

The human-centric approach to AI strives to ensure that human values are central to the way in which AI systems are developed, deployed, used and monitored, by ensuring respect for fundamental rights, including those set out in the Treaties of the European Union and Charter of Fundamental Rights of the European Union, all of which are united by reference to a common foundation rooted in respect for human dignity, in which the human being enjoy a unique and inalienable moral status. This also entails consideration of the natural environment and of other living beings that are part of the human ecosystem, as well as a sustainable approach enabling the flourishing of future generations to come.

Internet of Things (IoT)

Infrastructure of interconnected entities, people, systems and information resources together with services which process and react to information from the physical world and virtual world

Machine Learning

Machine Learning (ML) is a branch of Artificial Intelligence (AI) that focuses on the development of systems capable of learning from data to solve an application problem without being explicitly programmed. Learning refers to the computational process of optimizing model parameters from data, according to a given criteria. The model is a mathematical construct that generates an output based on input data.

Robot

Automation system with actuators that performs intended tasks in the physical world, by means of sensing its environment and a software control system.

Note 1 to entry: A robot includes the control system and interface of a control system.

Note 2 to entry: The classification of robot into industrial robot or service robot is done according to its intended application.

Note 3 to entry: In order to properly perform its tasks, a robot makes use of different kinds of sensors to confirm its current state and perceive the elements composing the environment in which it operates.

Robotics

Science and practice of designing, manufacturing, and applying robots.

Virtual Reality

Virtual Reality is an alternate world filled with computer-generated images that respond to human movements.