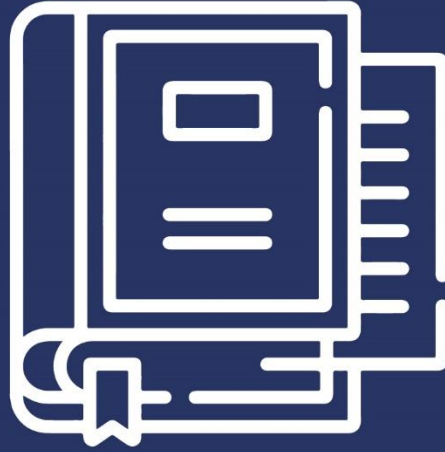


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Appendix 10.

Additive Manufacturing and Entrepreneurship Training Curricula

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AM Virtual Training Modules			Topics	Lead Partner
Beginner	0	Beginner for AM	Overview on AM processes, Classification of AM processes, the ASTM/ISO/NADCAP classification of AM technologies, main characteristics, advantages and manufacturing constraints, polymer basic principles, polymer material knowledge, polymer constraints, metal basic principles, metal material knowledge, metal powder metallurgy, metal constraints, metal application, design for AM main concepts and objectives, design for AM 3D modeling, design for AM analyses based design, design for AM design optimization and topology, design for AM shape complexity, design for AM (DfAM) rules, biomimetic design approach, main concepts on the whole process planning chain, use of common AM software	CEF
Intermediate	1	Design for AM	Mechanical and Thermal Analysis, Software implementation, Analysis of FEM results	Gazi
	2	Design and Analysis	Mechanical and Thermal Analysis, Software implementation, Analysis of FEM results	UPM
	3	Process Development	Thermal Analysis, Distortion Analysis, strain analysis, support structure analysis, orientation analysis	UNIBO
	4	Numerical Simulation	Thermal Analysis, Distortion Analysis, strain analysis, support structure analysis, orientation analysis	UPM
	5	Inspection and Quality Control	Non-destructive Testing Methods, Mechanical Testing methods, Microstructural Analysis, SEM, CT Analysis, Surface Topography Measurements Methods, Dimensional and tolerance measurements and analysis	Infotron
Advanced	6	Post Processing Methods	Surface enhancements methods, Heat Treatment, Support Removal, Finishing etc.	CESOL
	7	AM Standards & Cost Analysis	Standardization and cost estimation (material, energy, operating etc.)	EPMA
	8	Advanced AM Techniques	AI in AM, Micro-Nano Printing, Bioprinting, 4D Printing, Hybrid AM, FGM and Smart Materials, environmental and social implications	Infotron
	9	Practical Application Theoretical	Production Planning & Preparation, industrial and business case models, Process Optimization and Simulation, Machine Operation, raw material handling (loading and depowdering etc.), Workshop Production, Post Processing, testing and Inspection, Maintenance of AM machine and its units	Gazi
	10	Practical Application Practical Cases	Structural design for AM, WAAM technology and manufacturing, WAAM application and testing	UNIBO

Entrepreneurship Training Modules	Topics	Lead Partner
1	Testing entrepreneurship features, business idea Activity Description (including profile of participants per organization, goals and results of the activity) development and creativity exercises	UNIBO
2	The concept of business plan and its components (market research, marketing plan, production plan, management plan, financial plan)	UNIBO
3	Workshops to reinforce business plan elements (market research, marketing plan, production plan, management plan, financial plan)	Cesol
4	Issues to be considered in writing and presenting the business plan, Entrepreneurial Person Profiles and Evaluating Opportunities	CEF
5	Enterprise Finance and Financial Management	LOT
6	Business Model and Enterprise Strategies	Cesol
7	Technology and Innovation Management	CEF
8	AM-themed entrepreneurship examples and hands-on learning contents	Gazi

Module 0. Additive Manufacturing Beginner Level

Section 1. General Information	
Title of the Course/Training	Additive Manufacturing Beginner Level Training
Language of Instruction	English
Level of Course/Training Unit	Beginner
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 2 weeks (36 recorded lectures + 23 pptx + 23x10min self-assessment + extra material)
Objectives of the Course/Training	Introduction to Additive Manufacturing, AM Processes, AM Design Perspective
Prerequisites and co-requisites	Basic design knowledge
Course/Training Coordinator	Emine Cansu Türkkan
Assessment/verification	Written final test
Final certificate	Application and Exams (test at the end of every module)
Name of Lecturers/Trainers	Emine Cansu Türkkan Ömer Faruk Yazıcı Oğuz Kaan Öztürk Furkan Aykanat Dilara Ergin Ahmed Taha Çamlı Furkan Erçel

Section 2. Teaching Material	
Resources	
Suggested main Text Books	Additive Manufacturing Technologies - Ian Gibson, David W. Rosen, Brent Stucker Practical 3D Printers - Brian Evans Fabricated: The New World of 3D Printing - Hod Lipson, Melba Kurman Additive Manufacturing: Materials, Processes, Quantifications, and Applications - Kun Zhou 3D Printing and Additive Manufacturing: Principles and Applications - Chee Kai Chua, Kah Fai Leong The 3D Printing Handbook - Ben Redwood
Additional material	Youtube Videos

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Tests	23	Multiple choices
Homework	/	/
Projects	/	/
Final test	/	/
Other type	/	/

Section 4. Learning Outcomes (Upon the successful completion of this course/training, students/attendees will be able to:)	
Learning Outcomes	
1	Understanding the basics: Gain a foundational understanding of additive manufacturing, including its principles, terminology, and various processes involved.
2	Knowledge of AM materials: Learn about different types of materials used in additive manufacturing, such as polymers, metals, and composites. Understand their properties, capabilities, and limitations.
3	Familiarity with AM processes: Acquire knowledge of common AM processes. Understand the workflow, equipment, and parameters associated with each process.
4	Design for AM: Develop the ability to design parts optimized for additive manufacturing. Learn about design considerations, such as support structures, orientation, and tolerances, to ensure successful prints and maximize part performance.
5	Software proficiency: Gain proficiency in using CAD (Computer-Aided Design) software specifically tailored for additive manufacturing. Learn to create or modify designs that are compatible with AM processes.
6	Hands-on experience: Gain practical experience by operating an AM machine and performing basic tasks such as file preparation, print setup, and post-processing techniques.
7	Applications and case studies: Explore real-world applications of additive manufacturing across industries such as aerospace, automotive, healthcare, and consumer products. Analyze case studies to understand the value and benefits of AM in various contexts.
8	Resources and further learning: Familiarize oneself with relevant resources, industry publications, and professional networks to stay updated on the latest advancements and continue learning in the field of additive manufacturing.
9	Overall, the outcomes of a beginner level AM training should equip individuals with a solid understanding of the principles, processes, and practical aspects of additive manufacturing, enabling them to contribute effectively to AM projects and pursue further learning and specialization in the field.

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Introduction to Additive Manufacturing:										
1.1 Overview on AM Processes	Under the Introduction to Additive Manufacturing, an overview is given on AM's definition and its industrial significance. The section covers general AM processes, followed by classifications based on technology, material, and application. Standards like ASTM, ISO, and NADCAP guide these classifications, focusing on quality and process optimization. Additionally, key AM characteristics such as speed, precision, and material compatibility are discussed alongside the advantages and manufacturing constraints. This content offers a foundational understanding of AM technology's main components.	1	1 video 6 minutes	N/A	Bioprinting in Additive Manufacturing (Additional Resource - Printing Moving Parts in 3D Printer Projects (Additional Resource	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	5 PPT + 5 videos + 5 self-assessment test + 2 extra material
1.2 Classification of AM Processes		1	1 video 10 minutes							
1.3 The ASTM/ISO/NADCAP Classification of Additive Manufacturing Technologies		1	1 video 4 minutes							
1.4 Main Characteristics		1	1 video 7 minutes							
1.5 Advantages and Manufacturing Constraints		1	1 video 8 minutes							
2. Additive Manufacturing Methods-Polymers:										
2.1 Polymer Basic Principles	Under Additive Manufacturing Methods - Polymers, the focus is on the foundational principles of polymer-based AM, covering essential material properties and the science behind polymer behavior in additive processes. This section addresses material constraints, such as thermal and mechanical limitations, that affect process choices and application suitability. Real-world applications of polymer AM are discussed, emphasizing industries like automotive, healthcare, and consumer goods where polymers offer cost-effective and flexible solutions for complex designs.	1	1 video 16 minutes	N/A	Printing with a Resin 3D Printer (Additional Resource), Resin 3D Printing (Post Processing, Washing and Curing) (Additional Resource /Using FDM 3D Printer (Additional Resource	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	4 PPT + 4 videos + 4 self-assessment test + 3 extra material
2.2 Polymer Material Knowledge		1	1 video 9 minutes							
2.3 Polymer Constraints		1	1 video 25 minutes							
2.4 Polymer Application		1	1 video 8 minutes							
3. Additive Manufacturing Methods-Metals:										
3.1 Metal Basic Principle	In Additive Manufacturing Methods - Metals, the fundamentals of metal-based AM are introduced, including the key principles and properties of metals suited for additive processes. The section covers the basics of metal powder metallurgy, a critical part of metal AM that defines powder production, flowability, and particle size. Constraints such as thermal stress, oxidation, and support structure requirements are also discussed. Finally, real-world applications are highlighted, showcasing industries like aerospace, automotive, and medical, where metal AM enables highly durable and complex component production.	1	1 video 22 minutes	N/A	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	5 PPT + 5 videos + 5 self-assessment test
3.2 Metal Material Knowledge		1	1 video 11 minutes							
3.3 Metal Powder Metallurgy		1	1 video 3 minutes							
3.4 Metal Constraint		1	1 video 11 minutes							
3.5 Metal Application		1	1 video 9 minutes							

Section 5. Detailed Description of The Content

Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
4. Design for Additive Manufacturing:										
4.1 Design for Additive Main Concepts and Objectives	In Design for Additive Manufacturing (DFAM), the main concepts and objectives are introduced, emphasizing AM's unique design possibilities. This includes 3D modeling specific to AM needs, analysis-based design to ensure functionality, and optimization techniques like topology optimization for efficient material use. The section explores shape complexity, allowing intricate geometries, and DFAM rules to streamline production. A biomimetic design approach, inspired by nature, is also highlighted, showcasing how AM enables complex, lightweight structures not achievable through traditional methods.	1	1 video 7 minutes	N/A	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	7 PPT + 7 videos + 7 self-assessment test
4.2 Design for Additive 3D Modelling		1	1 video 4 minutes							
4.3 Design for Additive Analysis Based Design		1	1 video 14 minutes							
4.4 Design for Additive Design Optimization and Topology		1	1 video 14 minutes							
4.5 Design for Additive Shape Complexity		1	1 video 9 minutes							
4.6 Design for Additive DFAM Rules		1	1 video 9 minutes							
4.7 Biomimetic Design Approach		1	1 video 5 minutes							
5. Process Planning in Additive Manufacturing:										
5.1 Main Concepts on the Whole Process Planning Chain (Slicing, Path-Planning, Platform Optimization, Support Generation, Machine Code Generation)	In Process Planning in Additive Manufacturing, the focus is on the entire planning chain, which includes key concepts such as slicing, path planning, platform optimization, support generation, and machine code generation. Each of these elements is crucial for effective AM workflow and impacts the final part quality. The section also highlights the use of common AM software tools, like Cura and Magics, which aid in preparing and optimizing models for the additive manufacturing process, ensuring efficiency and accuracy in production.	1	1 video 19 minutes	Additive Manufacturing Technologies - Ian Gibson, David W. Rosen, Brent Stucker Practical 3D Printers - Brian Evans Fabricated: The New World of 3D Printing - Hod Lipson, Melba Kurman Additive Manufacturing: Materials, Processes, Quantifications, and Applications - Kun Zhou 3D Printing and Additive Manufacturing: Principles and Applications - Chee Kai Chua, Kah Fai Leong The 3D Printing Handbook - Ben Redwood	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	2 PPT + 2 videos + 2 self-assessment test
5.2 Use of Common AM Software (Cura, Magics, etc.)		1	1 video 8 minutes							

Module 1. Design for Additive Manufacturing

Section 1. General Information	
Title of the Course/Training	Design for Additive Manufacturing (DfAM)
Language of Instruction	English
Level of Course/Training Unit	Intermediate
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 2 weeks (6h of recorded lectures + 6x30min self-assessment + 1h final test) + extra material
Objectives of the Course/Training	Introduction to basic principles of AM and Design tools for AM
Prerequisites and co-requisites	Prerequisites are not mandatory
Course/Training Coordinator	Prof. Oguzhan Yilmaz
Assessment/verification	Design Project
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Mustafa Kas, Busra Aslan Cigir

Section 2. Teaching Material	
Resources	
Suggested main Text Books	1. Design for Additive Manufacturing, Elsevier, Martin Leary, eBook ISBN: 9780128168875 2. I. Gibson - Additive manufacturing technologies - Springer
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	5	Multiple choices
Homework	/	/
Projects	1	Design project will be given to comprehend the all topics of the Course
Final test	/	/
Other type	/	/

Section 4. Learning Outcomes (Upon the successful completion of this course/training, students/attendees will be able to:)	
Learning Outcomes	
1	Know the basics design rules for AM Processes
2	Understand the possibilities and limitations of AM
3	Understand the design workflow
4	Learn how to successfully design, optimise, build, and apply AM
5	Learn Technical Design Guidelines and generative design approach
6	Learning Design Thinking methodology
7	Use CAD software and able to design parts for AM
8	Learn Reverse Engineering and Biomimetic design approaches

Section 5. Detailed Description of The Content

Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Computer Aided Design Tools for AM	CAD/CAE/CAM software for AM, data format utilisation	1	1 video 30 minutes	References 1, 2,	https://www.youtube.com/watch?v=J7GqFFWbm8	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions	/	1 PPT + 1 video + 1 self-assessment test + extra material
2. Topology Optimisation	Truss-based methods, Volume-based methods, manufacturing Consideration in TO	1	1 video 28 minutes	References 1, 2,	https://www.youtube.com/watch?v=QLA92V_85_I	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge	/	1 PPT + 1 video + 1 self-assessment test + extra material
3. Generative Design	Design space, Design Constraints, Heuristic Approach, Part Consolidation	1	1 video 6 minutes	References 1, 2	https://www.youtube.com/watch?v=33vzF_pce0A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
		1	1 video 10 minutes							
		1	1 video 5 minutes							
4. Biomimetic Design and Reverse Engineering	Biomimetic design applications in AM, Digitilisation tools of pyhsical objects, STL mesh generation	1	1 video 12 minutes	References 1, 2	https://www.youtube.com/watch?v=thqBsd7fn3Y	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	2 PPT + 2 videos + 1 self-assessment test + extra material
		1	1 video 19 minutes							
5. DfAM and AM Processes	Design rules for basic AM Processes and Industrial Applications	1	1 video 11 minutes	References 1, 2	https://www.youtube.com/watch?v=xI50lksW6k4	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 1 video + 1 self-assessment test + extra material
6. Design for AM Project & Project Presentation	Design of AM Parts	1	1 video 11 minutes	References 1, 2	/	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	Test covering all modules with multiple-	1 PPT + 1 video + 1 self-assessment test + extra material + final test

Module 2. Design and Analysis

Section 1. General Information	
Title of the Course/Training	Design and Analysis
Language of Instruction	English
Level of Course/Training Unit	Intermediate
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	1 Week (30 hours): Direct Tuition (8 hours) + Independent Study: (20 hours) + Self-Assessment (2 hours)
Objectives of the Course/Training	Introduction to performance-oriented design and analysis of Additively Manufactured Components
Prerequisites and co-requisites	Prerequisites are not mandatory. Suggested Basic Design for AM
Course/Training Coordinator	José L. OCAÑA, A. GARCÍA-BELTRÁN
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Ignacio ANGULO, Francisco CORDOVILLA

Section 2. Teaching Material	
Resources	
Suggested main Text Books	[Text 1] Design for Additive Manufacturing, Elsevier, Martin Leary, eBook ISBN: 9780128168875. [Text 2] Additive Manufacturing Technologies, Third Edition, Ed.Springer, Gibson I., Rosen D., Stucker B., Khorasani M. [Text 3] Additive Manufacturing: Materials, Processes, Quantifications and Applications. J Zhang, Y. Jun.
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	-	-
Homework	-	-
Projects	-	-
Final test	1	Multiple choices
Other type	-	-

Section 4. Learning Outcomes	
Learning Outcomes	
1	Apply the basic design rules for AM Processes to the achievement of mechanical / thermal / functional component properties
2	Understand the possibilities and limitations of AM in relation with performance properties
3	Understand the design workflow related to components performance
4	Learn how to successfully design, optimise, build, and apply AM with mechanical / thermal / functionality constraints
5	Use appropriate CAD software for the performance-constrained design of AM'ed parts

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Introduction to Performance-Oriented Design and Analysis of Additively Manufactured Components	Introduction to Performance-Oriented Design and Analysis of additively manufactured components	1	1 video 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 1 video + self-assessment
2. Design for Optimized/Targetted Mechanical/Functional/Thermofluidynamic Performance	Presentation of the Design guidelines for the achievement of mechanical/functional/thermal performance of components manufactured by AM	1	3 videos 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 3 videos + self-assessment
3. Case analysis of representative targetted Mechanical/Functional performance	Presentation of different representative cases of design of AM components with mechanical/functional performance requirements	1	3 videos 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 3 videos + self-assessment
4. Case analysis of representative targetted Thermofluidynamic performance	Presentation of different representative cases of design of AM components with thermofluidynamic performance requirements	1	3 videos 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 3 videos + self-assessment
5. Step-by-Step Design of Representative Cases oriented to Project Presentation	Step-by-step presentation of the details of the design cases explained in the previous chapters	1	2 videos 120 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 2 videos + self-assessment

Module 3. AM Process Development

Section 1. General Information	
Title of the Course/Training	AM Process Development
Language of Instruction	English
Level of Course/Training Unit	Intermediate
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 2 weeks (6h of recorded lectures + 6x30min self-assessment + 1h final
Objectives of the Course/Training	Provide detailed knowledge of AM processes, printing strategies and printing process
Prerequisites and co-requisites	Prerequisites are not mandatory
Course/Training Coordinator	Michele Palermo
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Alessandro Ascari

Section 2. Teaching Material	
Resources	
Suggested main Text Books	1. K. Zhou & C. Han - Metal powder-based additive manufacturing - Wiley VCH 2. S. Kumar - Additive Manufacturing Processes - Springer 3. I. Gibson - Additive manufacturing technologies - Springer 4. AUTOMATION, PRODUCTION SYSTEM AND COMPUTER-INTEGRATED MANUFACTURING, M. P. Groover, 3rd Edition, Pearson Int. Edition. 5. S. Kalpakjian, "Manufacturing Engineering and technology", Addison-Wesley 6. J.A. Shey, "Introduction to Manufacturing Processes" McGraw-Hill
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	6	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Discriminate the main process parameters and their role on productivity, quality and printable geometries.
2	Understand the relationship between part orientation and nesting on the platform on productivity, quality and printable geometries.
3	Discriminate the different types of supports and supporting strategies in relation to the different processes and machines.
4	Understand the different scanning strategies and their role on productivity and characteristics of the printed parts.
5	Discriminate different potentials given by dedicated softwares in path programming.
6	Discriminate the different technologies suitable for monitoring and controlling additive manufacturing processes.

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT recorded videos, additional material, number of tests, final test
1. Process parameter selection										
1.1 General aspects	Definition of the main process parameters: heat source power, dposition/scanning speed, layer thickness, gas flow, etc. Role of the main process parameters on: deposition rate, surface roughness and quality, potential defects, etc.	1	1 video 16 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=GQYZZ10lodw	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
1.2 Powder/Fluid Bed		1	1 video 18 minutes		https://www.youtube.com/watch?v=NG0bAYBPo88					
1.3 Direct Deposition		1	1 video 20 minutes		https://www.youtube.com/watch?v=RU6Ecxz71mk&t=1005s					
2. Part orientation										
2.1 General aspects	Definition of the different strategies concerning part orientation as a function of: platform shape and dimension, number, variety, shape and dimension of workpieces to build, specific additive technology.	1	1 video 22 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=10ZvyjTsaws	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
2.2 Powder/Fluid Bed		1	1 video 24 minutes		https://www.youtube.com/watch?v=DgFQgTPENS_M					
2.3 Direct Deposition		1	1 video 18 minutes		https://www.youtube.com/watch?v=lmaNMgZ1C_Og					
3. Support generation										
3.1 General aspects	Definition of supports and of their main characterisitcs: shape, dimension, position, aims & scopes. Relationship between supporting strategies and specific additive technologies.	1	1 video 18 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=hAow3siLVgY	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
3.2 Powder/Fluid Bed		1	1 video 21 minutes		https://www.youtube.com/watch?v=Rx-WGIVXOsw&list=PLmA_xUJT-8U1Lb8YmsOmJktEw4YZlCH6px					
3.3 Direct Deposition		1	1 video 16 minutes		https://www.youtube.com/watch?v=6BvGbGKGQhI					

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
4. Scanning strategies	Definition of scanning strategies and specific considerations as a function of the specific additive technology. Relationship between scanning strategy and workpiece geometry: hollow, thin walled, bulk, lattice, etc.	1	1 video 18 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=kPHCuVLwvd8	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
4.1 General aspects		1	1 video 24 minutes		/					
4.2 Powder/Fluid Bed		1	1 video 22 minutes		https://www.youtube.com/watch?v=LFrkS39kNlg					
4.3 Direct Deposition										
5. Path planning	Path planning as a function of the specific additive technology: overview of software tools for "offline programming" of toolpath trajectories in powder/fluid bed and direct deposition technologies.	1	1 video 15 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=LXLCBkGVrso	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material
5.1 General aspects		1	1 video 12 minutes		/					
5.2 Powder/Fluid Bed		1	1 video 18 minutes		https://www.youtube.com/watch?v=4Xw2UDgyNKE					
5.3 Direct Deposition										
6. Process parameter control	Identification of the main monitoring strategies for controlling the quality of the additive process.	1	1 video 15 minutes	References 1, 2, 3 from Section 2	https://www.youtube.com/watch?v=owTxioSs66s	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	Test covering all modules with multiple-choice questions	3 PPT + 3 videos + 1 self-assessment test + extra material + final test
6.1 General aspects		1	1 video 15 minutes		https://www.youtube.com/watch?v=pilpagq4tFk					
6.2 Powder/Fluid Bed		1	1 video 11 minutes		https://www.youtube.com/watch?v=Ekn0ChfOgcQ					
6.3 Direct Deposition										

Module 4. Numerical Simulation

Section 1. General Information	
Title of the Course/Training	Numerical Simulation
Language of Instruction	English
Level of Course/Training Unit	Advanced
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	1 Week (30 hours): Direct Tuition (8 hours) + Independent Study: (20 hours) + Self-Assessment (2 hours)
Objectives of the Course/Training	Introduction to performance-oriented design and analysis of Additively Manufactured Components
Prerequisites and co-requisites	Prerequisites are not mandatory. Suggested Process Development course.
Course/Training Coordinator	José L. OCAÑA, A. GARCÍA-BELTRÁN
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Francisco CORDOVILLA, Ignacio ANGULO

Section 2. Teaching Material	
Resources	
Suggested main Text Books	[Text 1] Salmi, M. (Ed.): Modeling, Simulation and Data Processing for Additive Manufacturing, MDPI (2022). ISBN: 978-3-0365-2948-6 [Text 2] Gibson I., et al: Additive Manufacturing Technologies, 3rd Edition, Springer (2021). ISBN: 978-3-030-56126-0. [Text 3] Zhang, J., Jun, Y: Additive Manufacturing: Materials, Processes, Quantifications and Applications. Elsevier (2018). ISBN: 9780128121559
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	-	-
Homework	-	-
Projects	-	-
Final test	1	Multiple choices
Other type	-	-

Section 4. Learning Outcomes	
Learning Outcomes	
1	Understanding the multiphysics and multiscale nature of AM simulation approaches
2	Understanding the main physical phenomena in AM processes
3	Understanding the role of the experimental data to feed AM process simulations
4	Understanding the specific problems for the different AM technologies
5	Use of appropriate simulation software to solve the different phenomena in AM processes

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Introduction to numerical simulation of AM processes	Description of the most relevant physics phenomena to consider when carrying out the different AM processes, and the different multiscale approaches	1	5 videos 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 5 videos + self-assessment
2. Mechanical/thermal/microstructural analysis	Detailed review of the mechanisms that govern the behavior processes during the AM processes	1	5 videos 30 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 5 videos + self-assessment
3. SLM simulation tools implementations	Description of numeric tools for the simulation of phase-change materials	1	3 videos 20 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 3 videos + self-assessment
4. DED single track simulation tools implementation	Study of the consolidation of single tracks in AM Processes	1	4 videos 20 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 4 videos + self-assessment
5. DED full sample process simulation tools implementation	Study of simulation-based design rules for AM Processes and Industrial Applications	1	3 videos 20 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 3 videos + self-assessment
6. Design for AM Projects & Project Presentation	Step-by-step presentation of the details of several AM Process simulation cases oriented to a tentative final Project	1	8 videos 120 minutes	References 1, 2, 3 from Section 2	N/A	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 8 videos + self-assessment

Module 5. Inspection and Quality Control

Section 1. General Information	
Title of the Course/Training	Inspection and Quality Control
Language of Instruction	English
Level of Course/Training Unit	Advance
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	5 hours Training + 2 hours Tutoring + 1 hour assesment
Objectives of the Course/Training	Provide detailed inspection and quality control of AM processes
Prerequisites and co-requisities	Prerequisites are not mandatory.
Course/Training Coordinator	Rüveyda Tunali
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Serhan Akın
	Kerim Ceylan
	Rüveyda Tunali

Section 2. Teaching Material	
Resources	
Suggested main Text Books	1. Chua, Chee Kai, Chee How Wong, and Wai Yee Yeong. Standards, quality control, and measurement sciences in 3D printing and additive manufacturing. Academic Press, 2017. 2. Metals Handbook 9th Edition, Volume 9 Metallography and Microstructures, American Society for Metals, Metals Park, OH, 1985.
Additional material	https://www.google.com/url?sa=i&url=https%3A%2F%2Fnanovea.com%2Forganic-surface-topography-using-portable-3d-profilometer%2F&psig=AOvWaw0HVbXQeByBRzABY5BxGmC7&ust=1719898509421000&source=images&cd=vfe&opi=89978449&ved=2ahUKEwjWIP0Uj4WHAXvQVaQEHTeaDqWQr4kDegUIARDMAQ https://www.phasics.com/en/application-areas/material-inspection-waveguide-surface-analysis-lidt/surface-measurement-waviness-topography-roughness/ https://www.gdandtbasics.com/what-is-a-profilometer/ https://www.researchgate.net/figure/Primary-and-filtered-profiles-obtained-by-the-mechanical-contact-profilometer_fig4_350551142 https://www.zygo.com/products/metrology-systems/3d-optical-profilers https://orslabs.com/services/material-analysis/sem/ https://qd-europe.com/nl/en/products/spectroscopy/atomic-force-microscopes-for-research https://serc.carleton.edu/research_education/geochemsheets/techniques/CT.html https://www.zygo.com/applications/measurements/topography-texture https://www.mdpi.com/2673-8244/2/1/5 https://www.researchgate.net/publication/348093851/figure/fig2/AS:977300074020872@1610017903730/LPBF-process-parameters-laser-power-scanning-speed-hatch-spacing-and-layer-thickness.png https://www.google.com/search?sa_esv=4cb9e1f4d5fda1fa&sa_upv=1&rlz=1C1GCEU_trTR1104TR1104&q=Surface+topography+measurements+used+to+characterize+the+surface+properties+of+additively+manufactured+materials,+including+roughness,+porosity,+and+surface+morphology.&tbm=isch&source=lnms&fbs=AEQNm0CgMcZ11KbHg1uunEmuo39LURR2Id75hr48hPnE0Zxc9YswvPktu9pHnGyVAIH0RVD5UEm0hGRLf-rugd2_4hWv4JMLoTK8ANJlJgXDT9fVvY4gE7i1854QmLW57V8CFqhELIxcw0kC0o1zdmzGVg8KLDLrbx3uL43bGyFkPIMx1mGHli1JdjjZM2YGKDDgq6si&sa=X&ved=2ahUKEwj-lGsmYWHAXvYB9sEHQ51Dzg00pQJegQICxAB&biw=2400&bih=1288&dpr=0.8#imgrc=EOTYn92uN4IjVM https://www.researchgate.net/figure/Surface-topography-after-turning_fig3_338687535 https://arti90.com/design-for-additive-manufacturing-dfam/ https://www.phil-gmbh.eu/x-ray-computed-tomography-for-defect-analysis/ https://www.qualitymag.com/articles/96177-x-ray-ct-for-quality-assurance-of-metal-am-parts https://www.metal-am.com/articles/simple-and-standardised-x-ray-ct-testing-in-metal-3d-printing/ https://arti90.com/post-processing/ https://infotron.com.tr/3dsystems/geomagic-design-x/ https://en.wikipedia.org/wiki/Scanning_electron_microscope https://upload.wikimedia.org/wikipedia/commons/thumb/f/f0/First_Scanning_Electron_Microscope_with_high_resolution_from_Manfred_von_Ardenne_1937.jpg/220px-First_Scanning_Electron_Microscope_with_high_resolution_from_Manfred_von_Ardenne_1937.jpg https://en.wikipedia.org/wiki/Scanning_electron_microscope https://www.researchgate.net/figure/Microstructural-analysis-of-tissue-SEM-images-taken-of-the-superior-surface-at-6000_fig9_262845167 https://www.sciencedirect.com/topics/engineering/optical-microscope https://microbenotes.com/transmission-electron-microscope-tem/ https://www.nanowerk.com/nanotechnology-glossary/x-ray-diffraction-xrd.php https://www.salzgitter-mannesmann-forschung.de/en/we-support-you/investigation/microstructural-analysis.html https://www.slideshare.net/slideshow/vem-023-lesson-1pdf/266285434 https://www.salzgitter-mannesmann-forschung.de/en/we-support-you/investigation/microstructural-analysis.html https://www.researchgate.net/figure/Microstructural-Analysis-of-PP-SF-Soil-matrix-using-SEM_fig5_341179944 https://link.springer.com/article/10.1557/jmr.2020.120

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	7	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Understanding the general principles of NDTs, methods and techniques, applications in AM
2	Understanding the general principles of Mechanical testing methods and techniques, applications in AM
3	Understanding the different types of microstructures and materials, general information about phases of materials, solidification and crystallization mechanisms
4	Learning principles of SEM and applications in AM
5	Learning principles of CT analysis and applications in AM, advantages and disadvantages
6	Understand the general principles and methods of surface topography measurement methods
7	Learning basic GD&T terms and principles

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Non-destructive Testing Methods	Definition of commonly used NDT methods like: visual inspection, x-ray imaging and radiography, ultrasound, electromagnetic, thermography, penetrant testing, acoustic emission and their applications	1	1 video 30 minutes	ppt & video lecture	Bodor Core Technology: E	https://infotron.com.tr/3dsystems/geomagic-design-x/ https://www.phigmh.eu/x-ray-computed-tomography-for-defect-analysis/	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
2. Mechanical Testing methods	Definition of commonly used mechanical testing methods like: hardness, tensile, impact, fracture toughness, creep and fatigue and their application	1	1 video 30 minutes	ppt & video lecture	https://www.youtube.com/watch?v=FpQ2KlmasN0 https://youtu.be/G2JGNlvNC4 https://youtu.be/9jOWcENISW5 https://youtu.be/hASl6d3z3BM https://youtu.be/p00nMx-UUA https://youtu.be/7tr4kVtNsrM https://youtu.be/3_9HR64bVus	https://www.qualitymag.com/articles/96177-x-ray-ct-for-quality-assurance-of-metal-am-parts https://www.metal-am.com/articles/sample-and-standardised-x-ray-ct-testing-in-metal-3d-printing/ https://www.zeiss.com/metrology/services/measuring-services/ct-measurement.html	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
3. Microstructural Analysis	Definition of crystal structures, lattices, grain size and grain boundaries, orientation effects, material phases, volume fraction of phase constituents, precipitates and inclusions, voids, microcracks, dislocations	1	1 video 40 minutes	ppt & video lecture	N/A	https://www.qualitymag.com/articles/94884-industrial-ct-for-use-in-additive-manufacturing-inspection	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
4. SEM	Definition of microscopes and different imaging methods including SEM, and TEM	1	1 video 20 minutes	ppt & video lecture	N/A	https://www.zeiss.com/metrology/services/measuring-services/ct-measurement.html	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
5. CT Analysis	Definition of CT, working mechanism, applications and challenges	1	1 video 40 minutes	ppt & video lecture	N/A	https://www.youtube.com/watch?v=lcWjZbXfKfM&ab_channel=MaterialsScience2000	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
6. Surface Topography Measurements Methods	Definition of surface topography measurement methods like optical microscopy, AFM, surface roughness	1	1 video 20 minutes	ppt & video lecture	N/A	https://www.youtube.com/watch?v=lcWjZbXfKfM&ab_channel=MaterialsScience2000	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
7. Dimensional and tolerance measurements and analysis	Definition of GD&T terms, softwares, applications in AM	1	1 video 40 minutes	ppt & video lecture	N/A	https://www.youtube.com/watch?v=lcWjZbXfKfM&ab_channel=ZEISSIndustrialMetrology	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz

Module 6. Post Processing Methods

Section 1. General Information	
Title of the Course/Training	Post-processing Methods
Language of Instruction	English
Level of Course/Training Unit	Advance
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 2 weeks (3h of recorded lectures + 6x30min self-assessment + 1h final test) + extra material
Objectives of the Course/Training	Provide detailed knowledge of post-processing methods in AM
Prerequisites and co-requisites	Attendance to previous courses is strongly suggested. Trainees should have knowledge in materials
Course/Training Coordinator	Alberto Toledo
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Alberto Toledo

Section 2. Teaching Material	
Resources	
Suggested main Text Books	1. Gibson, I., Rosen, D., Stucker, B., Khorasani, M. (2021). Post-Processing. In: Additive Manufacturing Technologies. Springer, Cham. 2. Innovations in Additive Manufacturing (2022). Springer, Cham.
Additional material	1. https://www.youtube.com/watch?v=c08R4djd-gc 2. https://www.youtube.com/watch?v=KbBzXEpePOs

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	5	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Discuss methods to reduce straining, using different post-processes, for a variety of part geometries and AM processes.
2	Explain post-processing methods applicable to various AM processes as built parts.
3	Describe the effect of different heat treatments on microstructure, mechanical properties, residual stresses and defects.
4	Explain the characteristics that the as-built part must have/meet according to each post-process.

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. General Considerations	Surface roughness, Porosity, Anisotropy, Residual Stresses and Deformations. Important Key Performance Indicators. What is AM Post-processing? Why is it important? Classification of AM post-processing Methods	1	2 videos (9 + 9 minutes)	References 1, 2 from Section 2	Videos 1, 2 from Section 2	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 2 videos + 1 self-assessment test + extra material
1.1 AM Quality Related Challenges										
1.2 Introduction to AM Post-Processing										
2. Thermal Treatment	Preheating, sintering for Binder Jetting, Heat Treatment Basics and Methods. Heat Treatment Equipment, Temperature Measurement, Heat Treatment Parameters and Procedures	1	5 videos (11 + 9 + 10 + 11 + 9 minutes)	References 1, 2 from Section 2	Videos 1, 2 from Section 2	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 5 videos + 1 self-assessment test + extra material
2.1 Heat Treatment Methods										
2.2 Heat Treatment Equipment										
3. Plastic Deformation	What is Plastic Deformation. Shot Peening, Laser Peening, Rolling	1	4 videos (9 + 11 + 11 + 11 minutes)	References 1, 2 from Section 2	Videos 1, 2 from Section 2	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 4 videos + 1 self-assessment test + extra material
4. Subtractive Manufacturing	Comparison between Conventional and Non-Conventional post processes. Laser Ablation, Wire EDM, Grinding, Milling. Process selection	1	4 videos (9 + 9 + 9 + 12 minutes)	References 1, 2 from Section 2	Videos 1, 2 from Section 2	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 4 videos + 1 self-assessment test + extra material
4.1 Conventional vs Non-Conventional post processes										
4.2 Subtractive Processes for AM post-processing										
5. Cleaning and Finishing Operations	Powder removal, Support removal. Grinding, Mass finishing, Blasting, Abrasive flow, Electro-polishing	1	2 video (11 + 11 minutes)	References 1, 2 from Section 2	Videos 1, 2 from Section 2	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 2 videos + 1 self-assessment test + extra material
5.1 Necessary Operations										
5.2 Optional Operations										

Module 7. AM Standards & Cost Analysis

Section 1. General Information	
Title of the Course/Training	AM Standards & Cost Analysis
Language of Instruction	English
Level of Course/Training Unit	Intermediate
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 1 week (4h of recorded lectures + 4x15min self-assessment + 30 min final test) + extra materials
Objectives of the Course/Training	Provide detailed knowledge of standardisation & cost estimation (material, energy, operating etc.) in AM
Prerequisites and co-requisites	Attendance to previous courses is strongly suggested.
Course/Training Coordinator	Kenan Boz
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Kenan Boz

Section 2. Teaching Material	
Resources	
Suggested main Text Books	Post-processing related web sites, lectures notes, Youtube videos and presentations
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	4	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Broad knowledge & comprehension of standardisation activities
2	Recognize the standards applicable to additive manufacturing
3	Find the relevant standards to AM applications available in public repository
4	Identify the impact of qualification, certification and standardisation in the AM process chain
5	Understand the theory, principles and applicability of cost analysis
6	Describe AM cost models and their use in all stages of the process chain
7	Calculate the cost of a component fabricated with AM
8	Sustainability aspects of AM in terms of economics, Carbon footprint and Energy Consumption

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Standards & Standardisation Activities	Historical evolution and necessity of standards, Description of main Standardisation bodies: ISO, ASTM, DIN, etc., Working structures of ISO and ASTM.									
1.1 Development of standards		1	1 video 15 minutes	ppt files and videos for each lecture		N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	2 PPT + 2 videos + 1 self-assessment test + extra material
1.2 Standardisation Bodies		1	1 video 26 minutes							
1.3 Technical Committees										
2. Additive Manufacturing in Standardisation	Current activities of ISO/TC 261 and ASTM/F42. The joint working groups for harmonised standards, Audits and Certification procedures for standards related with AM, Role and importance of standards applicable in AM processes.									
2.1 Review of AM Standards		1	1 video 18 minutes	ppt files and videos for each lecture	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	3 PPT + 3 videos + 1 self-assessment test + extra material	
2.2 Relation of AM Standardisation with Qualification and Certification		1	1 video 10 minutes							
2.3 AM standards and the Process Chain		1	1 video 12 minutes							
3. Cost Analysis & Modeling	Activity based cost estimation, analytical cost estimation, breakdown approach, Identification of which types of costs to include and to define the scope of cost analysis. Categorisation of costs by type, Cost of labor, machine setup, and overhead. Cost occurring during processing. Costs incurred to bring the part to its final form. AM versus conventional manufacturing techniques, Life Cycle Analysis									
3.1 Cost Estimation Techniques		1	1 video 26 minutes	ppt files and videos for each lecture	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	2 PPT + 2 videos + 1 self-assessment test + extra material	
3.2 AM Cost Models										
3.3 AM Cost Methodology or pre-processing, processing and post-processing										
3.4 Sustainability in AM: Carbon footprint, material and energy consumption	1	1 video 16 minutes								
4. Additive Manufacturing Costs & Benefits	Investigation and analysis of labor, material, and machine costs, Costs associated with build failure, machine setup, and inventory. Application of the knowledge gained in the course on a practical real-life case study.									
4.1 Well-structured costs		1	1 video 26 minutes	ppt files and videos for each lecture		N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	2 PPT + 2 videos + 1 self-assessment test + extra material
4.2 Ill-structured costs										
4.3 Illustrative example										

Module 8. Advanced AM Techniques

Section 1. General Information	
Title of the Course/Training	Advanced AM Techniques
Language of Instruction	English
Level of Course/Training Unit	Intermediate
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	5 hours Training + 2 hours Tutoring + 1 hour assesment
Objectives of the Course/Training	Provide detailed inspection and quality control of AM processes
Prerequisites and co-requisities	Prerequisites are not mandatory.
Course/Training Coordinator	Ruveyda Tunali
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Ataberk Yapıcı

Section 2. Teaching Material	
Resources	
Suggested main Text Books	1. Sadasivuni, Kishor Kumar, Kalim Deshmukh, and Mariam Ali SA Al-Maadeed, eds. "3D and 4D printing of polymer nanocomposite materials: Processes, applications, and challenges." (2019). 2. Kumar, Ajay, Mittal, Ravi Kant, and Haleem, Abid, ""Advances in Additive Manufacturing: Artificial Intelligence, Nature-Inspired, and Biomanufacturing" (2022).
Additional material	Videos reported in Section 5

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	7	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Discuss machine learning, artificial intelligence and its applications in AM, future prospects
2	Understanding the mechanism of micro and nano printing and their applications and challanges, future prospects
3	Describe basics of bioprinting, applications, challenges, future prospects
4	Defining 4D printing, applications, challenges, future prospects
5	Discuss Hybrid printing, applications and challenges, future prospects
6	Describe FGM and Smart materials, applications in AM, challanges, future prospects
7	Discuss enviromental and social implications of AM, green deal and sustainability

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. AI in AM	Theoretical background, Designing with AI, generating toolpath via AI, applications	1	1 video 30 minutes	ppt & video lecture	Video 1: https://www.youtube.com/watch?v=Rrl4HshuzUw	https://doi.org/10.1016/j.jaime.2021.100032 https://doi.org/10.1051/mfreview/2020005 https://doi.org/10.1007/s00170-017-1345-3 https://doi.org/10.1016/j.addma.2018.03.010 DOI:10.1088/1757-899X/881/1/012015	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
2. Micro-Nano Printing	Theoretical background, Understanding the mechanism of micro and nano printing and their applications and challenges, future prospects	1	1 video 30 minutes	ppt & video lecture	N/A	DOI:10.1016/j.matdes.2021.110164 International Journal of Applied Engineering Research 13(22):16141-16151 Trends in 3d Printing Process for Biomedical Field: Opportunities and Challenges Volume 28, pages 1345-1367, (2020)	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
3. Bioprinting	Theoretical background, basics of bioprinting, applications, challenges, future prospects	1	1 video 40 minutes	ppt & video lecture	Video 1: https://www.youtube.com/watch?v=s3CJ26YSU Video 2: https://www.youtube.com/watch?v=mMeQjwH4NVU&t=85s	Fusion 360 Generative Design Hurni Engineering Boron 3D Metal Printing Functionally graded material by additive manufacturing. Proceedings of the 2nd International Conference on Progress in Additive Manufacturing (Pro-AM 2016), 206-211. Choy, S. Y., Sun, C. N., Leong, K. F., Tan, K. E., & Wei, J. (2016).	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
4. 4D Printing	applications, challenges, future prospects	1	1 video 20 minutes	ppt & video lecture	Video 1: https://www.youtube.com/watch?v=iU4Joc-yuM Video 2: https://www.youtube.com/watch?v=B-Bnm_IUts Video 3: https://www.youtube.com/watch?v=gJgV68KclU&t=1s	4D printing: Fundamentals, materials, applications and challenges AamirAhmed a, Sandeep Arya a*, Vinay Gupta b, HidemitsuFurukawa c, ***. Aijt Khosla c. ** (2021) DOI:10.3390/gels8070455 Video 3: Georgia Tech	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
5. Hybrid AM	Theoretical background, FGM and Smart materials, applications in AM, challenges, future prospects	1	1 video 40 minutes	ppt & video lecture	Video 1: https://www.youtube.com/watch?v=e7hFOQTKsf Video 2: https://www.youtube.com/watch?v=WyUObN8ocul	Thermorph: Democratizing 4D Printing of Self-Folding Materials and Interfaces CHI2018 Byoungkwon An*, Ye Tao*, Jianzhe Gu, Tingyu Cheng, Xiang 'Anthony' Chen, Xiaoxiao Zhang, Wei Zhao, Youngwook Do, Shigeo Takashi, Hsiang-Yun Wu, Teng Zhang and Lining Yao, Caltech.edu	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
6. FGM and Smart Materials	Understand FGM and Smart materials, applications in AM, challenges, future prospects	1	1 video 20 minutes	ppt & video lecture	Video 1: https://www.youtube.com/watch?v=rhJqb8XWHL4		Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz
7. Environmental, Safety and Social Implications	Discuss environmental and social implications of AM, green deal and sustainability & HSE	1	1 video 40 minutes	ppt & video lecture	N/A		Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	ppt learning material, video speech, multiple choice quiz

Module 9. Practical Application (Theoretical)

Section 1. General Information	
Title of the Course/Training	Practical Application
Language of Instruction	English
Level of Course/Training Unit	Advanced
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 1 week (30 min of recorded lectures + 9x15min self-assessment + 1h final test) + extra material
Objectives of the Course/Training	Undertand the theoretical background of AM Applications
Prerequisites and co-requisites	Prerequisites are not mandatory
Course/Training Coordinator	Prof. Oguzhan Yilmaz
Assessment/verification	Final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Prof. Oguzhan Yilmaz

Section 2. Teaching Material	
Resources	
Suggested main Text Books	[1] A guide to Additive Manufacturing, Springer Tracts in Additive Manufacturing, OPEN ACCESS, [2] Additive Manufacturing Technologies, Third Edition, Ed.Springer, Gibson I., Rosen D., Stucker B., Khorasani M.
Additional material	[1] A practical guide to design for Additive Manufacturing, Ed. Springer, Olaf Diegel , Axel Nordin , Damien Motte [2] Handbook of sustainability in Additive Manufacturing, Volume 1, Ed. Springer, Subramanian Senthilkannan Muthu, Monica Mahesh Savalani [3] Handbook of sustainability in Additive Manufacturing, Volume 2, Ed. Springer, Subramanian Senthilkannan Muthu, Monica Mahesh Savalani [4] The management of Additive Manufacturing, Enhancing Business Value, Ed. Springer, Mojtaba Khorram Niaki , Fabio Nonino [5] Standards, Quality Control and Measurement Sciences in 3D Printing and Additive Manufacturing, Chee Kai Chua, Chee How Wong and Wai Yee Yeong [6] Modeling and Simulation of Functionalized Materials for Additive Manufacturing and 3D Printing: Continuous and Discrete Media, Ed. Springer, Tarek I. Zohdi [7] Additive Manufacturing - Developments in Training and Education, Ed. Springer, Eujin Pei, Mario Monzón, Alain Bernard

Section 3. Self-Assessment Tests and Final Test		
In-Term Studies	Quantity	Description
Intermediate tests	9	Multiple choices
Homework	/	/
Projects	/	/
Final test	1	Multiple choices
Other type	/	/

Section 4. Learning Outcomes	
Learning Outcomes	
1	Prepare the AM process plan and able to do production plan
2	Able to do AM process optimisation
3	Understand machine operation for AM Processes
4	Understand the material handling for AM raw materials
5	Plan workshop production
6	Know the maintenance and repair steps for AM machines
7	Understand the testing and inspection procedure in AM processes

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Production Planning and Preparation	Explaining the production steps from design to quality control. Giving two AM Process examples and defining the each steps.	1	1 Video 25 Minures	References 1, 2	https://www.youtube.com/watch?v=1Ff_NcZh8So	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 1 videos + 9 self-assessment tests + extra material + 1 Final test
2. Industrial and Business Case Models	Explaining the differences of traditional manufacturing and additive manufacturing workflow.				/	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	
3. Process Optimisation and Simulation	Explaining the process optimisation tools: Design optimisation, Numerical Simulations, Process Optimisation and Analyses. Simulation tools, such as multi-physics, heat source, melt-pool, residual stress and distortion analyses are explained.				https://www.youtube.com/watch?v=12wHtBYqtg4	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	
4. Machine Operation	All the steps including machine preparation, leading material, built platform leveling, print file preparation, post-processing and maintenance etc.				https://www.youtube.com/watch?v=qoBU0r7pT84	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	
5. Raw Material Handling	How to storage, handling, loading and unloading, inspection, cleaning, quality control of raw materials used in different AM processes are explained.				/	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	

Section 5. Detailed Description of The Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
6. Workshop Production	How AM processes are in action in production is explained.	1	1 Video 25 Minures	References 1, 2	/	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	1 PPT + 1 videos + 9 self-assessment tests + extra material + 1 Final test
7. Post Processing	Different post-processing techniques, such as support removal, sand blasting, polishing, painting, support removal, and polishing are explained.				https://www.youtube.com/watch?v=NLoB52nPua0&list=PL3lUrnJwJW5nKT71mMX7Luyaliyb_Blv	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	
8. Testing & Inspection	Different testing and inspection techniques to be used in AM parts are explained.				/	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	/	
9. Maintenance of AM Machine and its Units	Maintenance of AM Machine and its units are detailed in different basis, such as daily, weekly, monthly, Quarterly, Annually and as needed. Two different AM processes are given as an example.				https://www.youtube.com/watch?v=v8SwY8yveqc	N/A	Multiple-choice questions	Students could look for online material (videos, white papers, etc.) to deepen their knowledge and promote fruitful discussions during the lessons	Test covering all modules with multiple-choice questions	

Module 10. Practical Applications

Section 1. General Information	
Title of the Course/Training	Practical Applications
Language of Instruction	English
Level of Course/Training Unit	Advanced
Target Audience	Un-Skilled/Non-Technical/Technical Persons
Duration	Total duration of 2 weeks (6h of recorded lectures + 1h self-assessments) + additional videos and papers
Objectives of the Course/Training	Provide knowledge on the Wire and Arc Additive Manufacturing (WAAM) technology, outlining design approach for WAAM structural elements, followed by manufacturing of an optimized structural element and experimental tests on WAAM specimens.
Prerequisites and co-requisites	Prerequisites are not mandatory
Course/Training Coordinator	Michele Palermo
Assessment/verification	Written final test
Final certificate	Certificate upon Completion
Name of Lecturers/Trainers	Michele Palermo
	Lidiana Arrè
	Vittoria Laghi
	Tomaso Trombetti
	José Antonio Dieste
	Filomeno Martina

Section 2. Teaching material	
Resources	
Suggested main Text Books	Additive Manufacturing for Construction, <i>Biranchi Panda, Pshtiwan, Vittoria Laghi</i> , ICE Publishing, 2023
Additional material	1) Recorded lectures from previous seminars on WAAM in Construction 2) Additional tutorials: - internship experience - experimental tests (e.g. tomography test) 3) Papers on WAAM

Section 3. Self-assessment tests and final test		
In-Term Studies	Quantity	Description
Intermediate tests	3	Multiple choice at the end of each of the three topics
Homework	/	/
Projects	/	/
Final test	/	/
Other type	/	/

Section 4. Learning Outcomes: Upon the successful completion of this course/training, students/attendees will be able to:	
Learning Outcomes	
1	Understand the possibilities offered by WAAM for the fabrication of large-scale structures, particularly in the construction sector.
2	Gain an overview of pioneering WAAM applications for developing novel geometries.
3	Understand the main characteristics of WAAM elements from both geometrical and mechanical perspectives.
4	Acquire knowledge about the WAAM process and how the printing process affects the 3D printed elements.
5	Understaing how to design a novel structural element tailored to WAAM, while considering manufacturing constraints, geometrical and mechanical irregularities.
6	Understanding the capabilities offered by tomography testing and how to interpret the obtained results.

Section 5. Detailed description of the Content										
Module title	Content	Power point presentations	Recorded Lecture videos	Main teaching material	Other videos (from other sources)	Additional materials	Self assessment tests	Homework/ projects	Final test	Overall structure of the lecture
	Brief description of the content	Description of the organization and number of PPTs to be provided for each module	Description of the structure, number and expected duration of the recorded videos for each module	Books and lecture hand notes prepared by the lecturer	Additional videos from external sources (Youtube,...)	Scientific papers, readings, tutorial, other type of material,...	Describe the type of test: multiple-choices, open questions,...	Provide details on whether homework is required. If so, describe the type of homework, or project, and provide instructions on how the student should develop it	Describe the final test	Summarize the overall structure of the module. E.g. number and sequence of PPT, recorded videos, additional material, number of tests, final test
1. Structural design for AM	The module 10 comprises two main contributions: the first one related to the material from lectures provided during the Summer School "WAAM in Construction" held at the University of Bologna in 2023, and a second contribution presenting the case study of a novel structural element, from the conceptual design up to its fabrication and testing campaign.									
Module organization and contributions	The introduction to metal 3D printing in construction provides information on the interdisciplinary effort required to fabricate WAAM elements: from conceptualization and design to possible applications and demonstrators.	1	1 video 5 minutes	Additive Manufacturing for Construction	N/A	Video by master's student: internship experience on WAAM	5 multiple-choice questions	N/A	N/A	3 PPTs + 3 videos + additional materials + self-assessment
Interdisciplinary approach		1	1 video 5 minutes							
Metal 3D Printing in Construction. An overview of its role in Structural Engineering		1	1 video 1 hour and 10 minutes							
2. WAAM technology and manufacturing	The WAAM process is presented, outlining its main characteristics and pioneering applications. Then, current knowledge on geometrical and mechanical characterization of WAAM elements is presented. Following this, a presentation of the fabrication of large-scale elements by the AITIIP company is provided, followed by the combined application of WAAM with other 3D printing process. In conclusion, various WAAM processes, from CMT to CWMIG, are presented, along with the estimation of product LCA environmental impact provided by the WAAM3D company.									
WAAM in Construction: general aspects		1	1 video 10 minutes	Additive Manufacturing for Construction	https://youtu.be/lxqidzv_VGI?feature=shared	10 PAPERS ON WAA10 PAPERS ON WAAM + video by AITIIP	10 multiple-choice questions	N/A	N/A	5 PPTs +5 videos + additional materials + self-assessment
WAAM in Construction: Characterization of metal 3D printed elements		1	1 video 1 hour and 30 minutes							
WAAM for large-scale structures: fabrication		1	2 videos: 5 minutes and 30 minutes							
WAAM in Construction: Combining WAAM with other construction materials		1	1 video 40 minutes							
Comparative LCA assessment		1	1 video 1 hour and 10 minutes							
3. WAAM application and testing	The case study of a WAAM structural element is presented here. The conceptual design of this novel geometry tailored to WAAM is outlined. Subsequently, the fabrication phase and testing campaign are detailed, particularly highlighting the tomography test and the interpretation of the results.									
Design		1	1 video 15 minutes	Additive Manufacturing for Construction	N/A	1. Two videos by TEC Eurolab testing company 2. video by master's student on tomography tests (internship experience)	5 multiple-choice questions	N/A	N/A	2 PPTs + 2 videos + additional materials + self-assessment
Fabrication and testing		1	1 video 15 minutes							

Entrepreneurship Module 1.

TITLE OF THE MODULE: Testing entrepreneurship features, business idea Activity Description (including profile of participants per organisation, goals and results of the activity) development and creativity exercises

LEADING ORGANIZATION: UNIBO

INSTRUCTOR: Prof. Laura Toschi

MAIN CONTENTS:

This module has the aim to introduce the main concepts related to the field of entrepreneurship. It first defines what an entrepreneurial process is, what characterizes an entrepreneur in terms of behavioral traits, and how an entrepreneurial idea can become successful into the market allowing a startup to become a unicorn, that is a company valued at more than \$1 billion. In the second part, the module discusses what an entrepreneurial opportunity is, which are its characteristics and describes the creative and innovative process which leads to the identification of business opportunities, with a focus on the importance to create connections among apparently disconnected elements.

REFERENCES:

Venkatraman, S. 1997. The distinctive domain of entrepreneurship research. In *Advances in Entrepreneurship, Firm Emergence and Growth*, Volume 3, pp. 119–138. JAI Press.

Sarasvathy, S.D 2001. Causation and effectuation: Towards a theoretical shift from economic inevitability to entrepreneurial contingency. *Academy of Management Review*, 26(2), 243–288.

Entrepreneurship Module 2.

TITLE OF THE MODULE: The concept of business plan and its components (market research, marketing plan, production plan, management plan, financial plan)

LEADING ORGANIZATION: UNIBO

INSTRUCTOR: Prof. Laura Toschi

MAIN CONTENTS:

This module presents one of the most important tools to develop a startup: the business plan. The business plan is the executive document that explains what a new business intends to accomplish. In particular, the module provides a detailed description of three sections of the business plan. First, the industry analysis is discussed to emphasize the importance to understand the competitive landscape of the new business. Both quantitative and qualitative instruments for performing this analysis are suggested, ranging from the 5 competitive forces by Porter, the value curve, and the PESTEL framework. Moreover, useful databases to gather data for the performance of such analysis are provided. Second, it is discussed the market analysis which aims at understanding what the customer target of the business is, how to define an effective value proposition to make the entrepreneurial opportunity distinctive and how to gather data through qualitative techniques like surveys, focus groups and interviews. Finally, the financial plan is introduced to explain how financial investors like Venture Capitalists evaluate new business.

REFERENCES:

Porter ME (1980). Industry structure and competitive strategy: keys to profitability. *Financ Anal J* 36:30–41.
Kim WC (2005). Blue ocean strategy: from theory to practice. *California Management Review*, 47(3): 105-121.

Entrepreneurship Module 3.

TITLE OF THE MODULE: Workshops to Reinforce Business Plan Elements

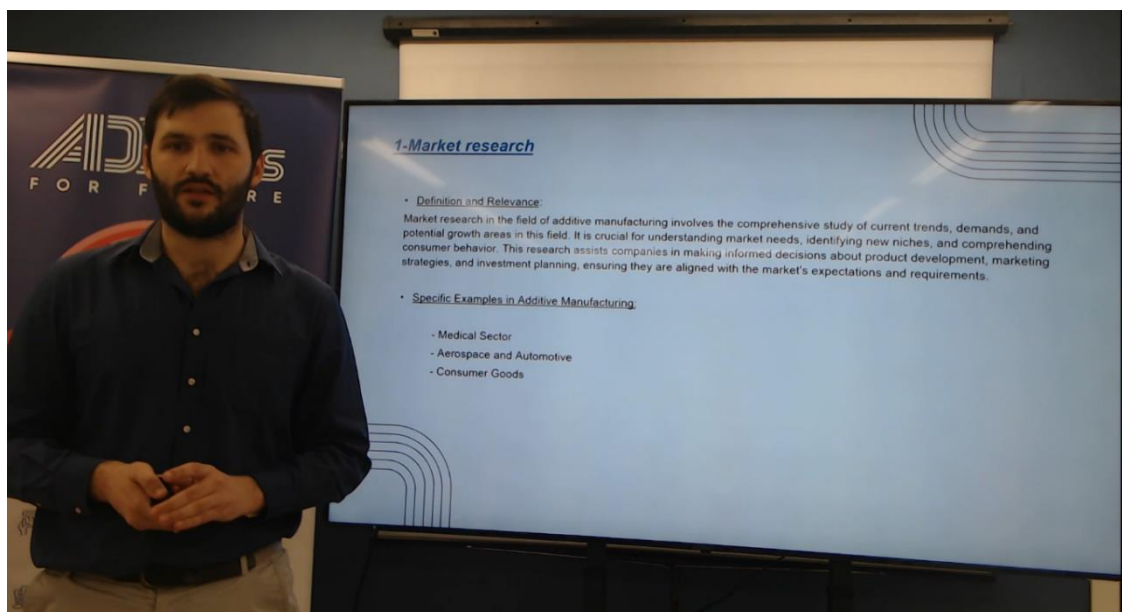
LEADING ORGANIZATION: Cesol

INSTRUCTOR: Victor Moreta

MAIN CONTENTS:

The module "Workshops to Reinforce Business Plan Elements" focuses on guiding participants through the essential components of a business plan, offering practical insights and hands-on exercises to strengthen their understanding. This module includes the following key topics:

1. **Market Research:** This section emphasizes the importance of understanding your target market, competition, and industry trends. Participants will learn how to conduct surveys, analyze customer behavior, and evaluate market demand. Tools and techniques such as SWOT analysis and customer segmentation are covered to help businesses define their niche and identify opportunities and threats in their market.



2. **Marketing Plan:** This section focuses on creating a clear plan to promote products or services. Participants will learn how to develop marketing objectives, choose appropriate marketing channels (online, offline, or both), and create compelling value propositions. The workshop also covers digital marketing tools, customer relationship management (CRM), and how to allocate resources for an effective marketing campaign.

2-Marketing plan

Marketing in Additive Manufacturing:

•**Explanation:** Marketing in additive manufacturing focuses on highlighting the unique features of the technology, such as the ability to produce complex and customized designs that are not possible with traditional methods. This marketing approach should reflect innovation and customization as its main appeals.

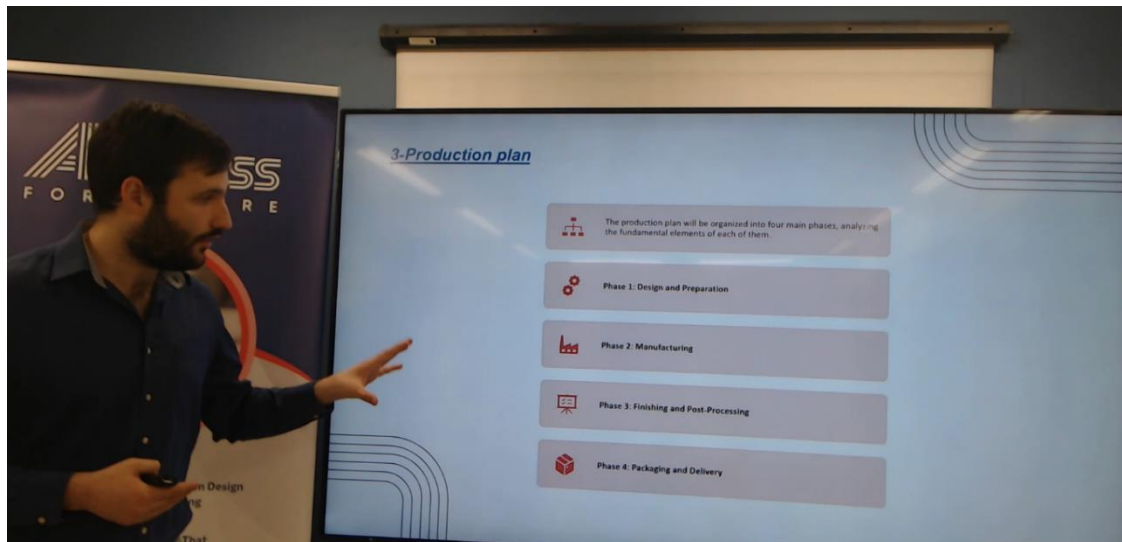
•Key Aspects:

- **Innovation:** Show how additive manufacturing is at the forefront of technology and production.
- **Customization:** Emphasize the ability to tailor products to the specific needs and preferences of each customer.
- **Efficiency:** Highlight the reduction in costs and production time, as well as the minimization of waste.

Basic Marketing Strategies:

- Content Marketing:** Create educational and engaging content that explains the advantages of additive manufacturing, including case studies, blogs, and videos showcasing the process and final products.
- Digital Marketing:** Use online platforms to reach a broader audience, including social media, online advertising, and email marketing.
- Public Relations:** Build relationships with media outlets and opinion leaders to gain coverage on advances and success stories in additive manufacturing.
- Direct Marketing:** Send personalized communications to potential or existing customers, especially those in industries that could significantly benefit from additive manufacturing.

3. **Production Plan:** This section focuses on the operational aspects of a business, such as manufacturing, supply chain management, and service delivery. Attendees will explore topics like production schedules, quality control, inventory management, and supplier relationships. The workshop will help participants align production capacity with market demand, ensuring operational efficiency.



4. **Management Plan:** In this part, participants will focus on building a strong management team, defining roles and responsibilities, and establishing a clear organizational structure. Leadership styles, human resources management, and succession planning are key areas of discussion to ensure effective team management and long-term sustainability.

4-Management plan

The management plan is very extensive, making a brief summary you can identify 11 control points, although this depends a lot on the organizational scope of each company, which will depend on the certifications you want to achieve.

Initially these are the points to discuss:

1. Vision and Strategic Objectives:
2. Market and Competition Analysis:
3. Product Development:
4. Supply Chain Management:
5. Manufacturing Operations:
6. Financial Management:
7. Human Resources and Team Management:
8. Marketing and Sales:
9. Risk Management and Regulatory Compliance:
10. Technology and Innovation:
11. Sustainability and Corporate Social Responsibility:

5. **Financial Plan:** This section covers the financial aspects of running a business, including budgeting, forecasting, and cash flow management. Participants will learn how to create income statements, balance sheets, and cash flow projections, along with strategies to secure funding and manage business finances for profitability and growth.

5- Financial Plan

When developing a financial plan, it is necessary to be clear about certain basic financial concepts and what the steps are to carry out the financial plan.

Basic Financial Concepts Applied to Additive Manufacturing	Steps to Create a Solid Financial Plan
<u>Initial Investment</u>	<u>Setting Financial Goals</u>
<u>Cash Flow</u>	<u>Feasibility Analysis</u>
<u>Break-even Point</u>	<u>Investment Planning</u>
<u>Profitability Analysis</u>	<u>Working Capital Management</u>
<u>Cost Management</u>	<u>Financing Strategies</u>
<u>Return on Investment (ROI)</u>	<u>Budget Control and Monitoring</u>
<u>Budgets and Financial Forecasts</u>	<u>Preparation for Contingencies</u>

Entrepreneurship Module 4.

TITLE OF THE MODULE: Issues to be Considered in Writing and Presenting the Business Plan, Entrepreneurial Person Profiles, and Evaluating Opportunities

LEADING ORGANIZATION: Archi's Academy

INSTRUCTOR: Thoufeeque Saheer Kalathilparmbil (Founder & CEO, Archi's Academy)

MAIN CONTENTS

This module focuses on the crucial elements of creating and delivering an effective business plan, the traits of successful entrepreneurs, and the strategies for evaluating business opportunities. It aims to provide listeners with the necessary tools and knowledge to navigate the complex landscape of entrepreneurship.

The first part of the module covers the structure and essential components of a business plan, including the executive summary, market analysis, organizational structure, product or service description, and financial projections. Emphasis is placed on the importance of clear, concise, and compelling communication in both written and verbal presentations. Audiences will learn how to align their business plans with the expectations of potential investors, using data-driven insights and realistic financial forecasts to build credibility.

The module also explores the characteristics of successful entrepreneurs, such as resilience, creativity, and risk-taking. The audience will engage in self-assessment exercises to identify their entrepreneurial strengths and areas for development.

The final section focuses on opportunity evaluation, guiding audiences through methods like SWOT analysis, Porter's Five Forces, and the Business Model Canvas. These tools help in assessing the viability and potential impact of business ideas. Real-world case studies and interactive exercises will be used to demonstrate how to identify and capitalize on market gaps effectively.

FIGURES FROM THE PRESENTATIONS

Figures include templates for business plan sections, graphs illustrating market analysis techniques, and models showcasing the business opportunity evaluation process. These visual aids will support listeners in applying theoretical concepts to practical scenarios, enhancing their learning experience.

REFERENCES

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. Wiley.

Blank, S., & Dorf, B. (2012). *The Startup Owner's Manual: The Step-by-Step Guide for Building a Great Company*. K & S Ranch.

Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. Crown Business.

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Entrepreneurship Module 5.

TITLE OF THE MODULE: Enterprise finance and financial management

LEADING ORGANIZATION: LOT-CONSULT

INSTRUCTOR: Mario Kamenov

MAIN CONTENTS:

The module presents the basics of enterprise finance and financial management. It consists of three parts – Enterprise capital, Long-term and Short-term assets and Financial indicators. First, the capital structure and sources of funding the enterprise capital and its purpose are discussed. The capital is the foundation upon which business organizations are built. The different types of capital are explained, such as Equity capital, Share capital, Raised capital and lending and Working capital. Second it is discussed Long-term assets (tangible - company's property, plant, and equipment, also known as PP&E and non-tangible- long term investments, patents, copyright, franchises, goodwill, know-how, trademarks as well as software) and Short-term assets of the enterprise. Important indicators for monitoring of the assets performance, such as Long-term (Fixed) Asset Turnover Ratio, Machine Utilization and estimation of the size of material stocks, are presented. Finally, important financial indicators are introduced, to explain how an enterprise can assess its cash flows and to use them to make forecasts. Assessing cash flows is essential for evaluating a company's liquidity, flexibility, and overall financial performance. Indicators for assessing the performance, such as Net present value, Liquidity and Break-Even Point, are suggested.

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Entrepreneurship Module 6.

TITLE OF THE MODULE: Business Model and Enterprise Strategies

LEADING ORGANIZATION: Cesol

INSTRUCTOR: Victor Moreta

MAIN CONTENTS:

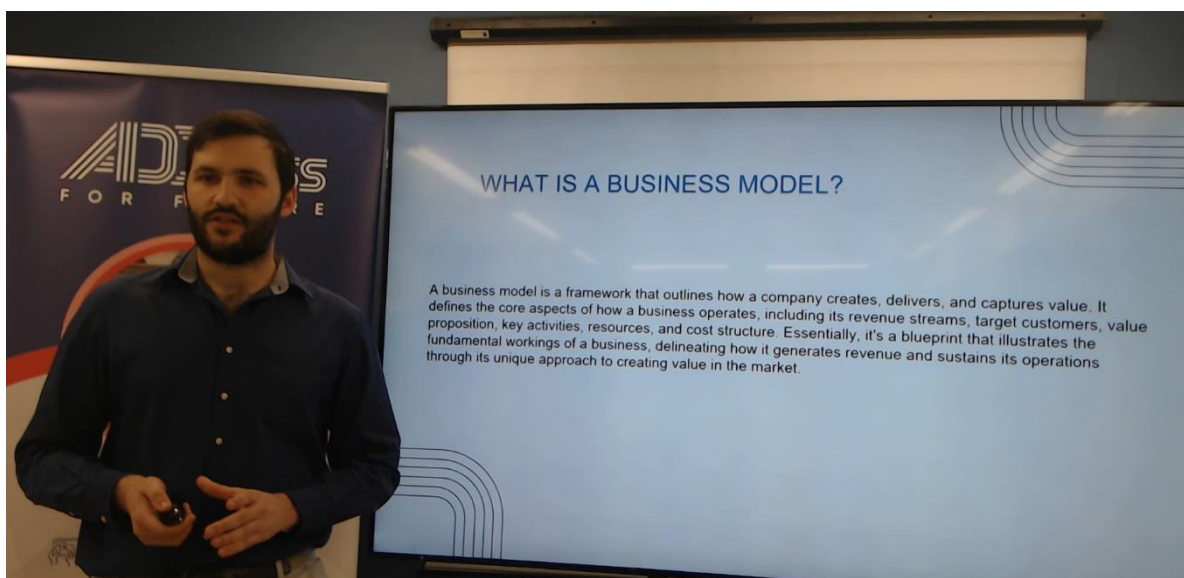
The module "Business Model and Enterprise Strategies" is designed to provide participants with in-depth knowledge of how to develop robust business models and innovative strategies that drive growth and competitiveness. The key topics covered include:

1. **Business Model:** This section focuses on creating a structured framework for how a business delivers value to its customers while ensuring profitability.

Participants will learn to design business models that are innovative and adaptable. Emphasis is placed on identifying and refining key components such as customer segments, value propositions, revenue streams, and cost structures.

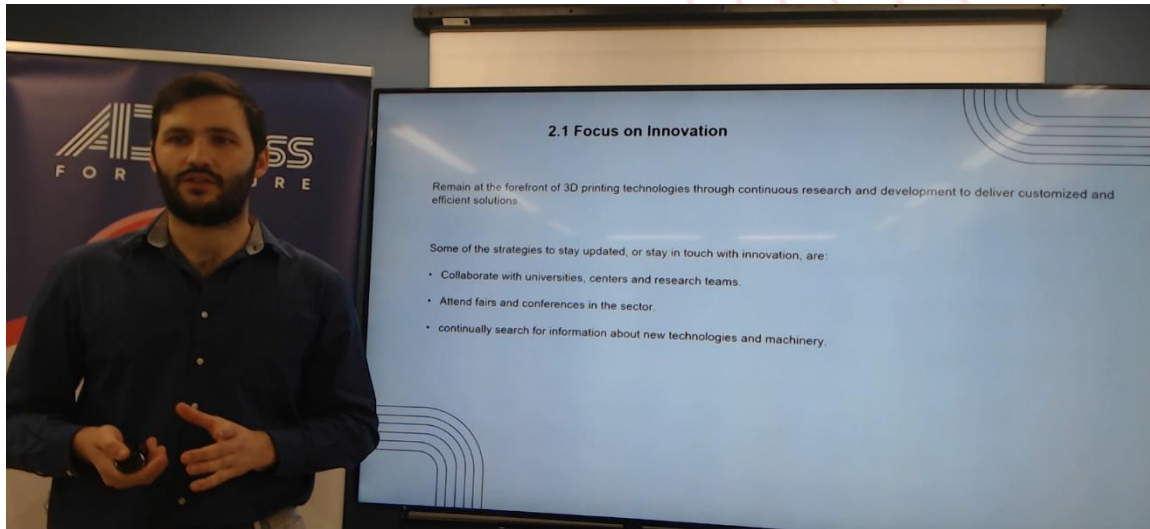
The workshop encourages participants to think creatively and explore different business models, including subscription, on-demand, or platform-based approaches.

A special focus is placed on innovation within the business model, ensuring that it can evolve with market trends and technological advancements to stay competitive.

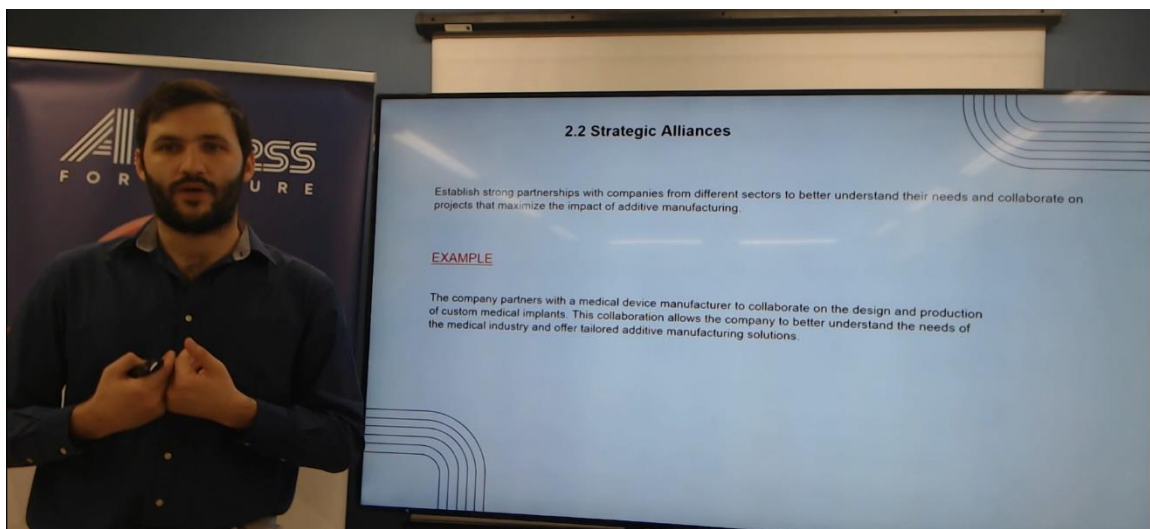


2. **Enterprise Strategies:** This section is focused on formulating dynamic strategies that help businesses grow, innovate, and compete effectively. Key themes include:

- **Innovation:** Participants will learn how to incorporate innovation into their strategy, exploring ways to continuously improve products, services, and processes.



- **Strategic Alliances:** The workshop covers the importance of forming partnerships and collaborations to expand market reach, access new technologies, and enhance competitive positioning.



- **Customization and Flexibility:** A focus on customer-centric strategies is emphasized, teaching businesses how to offer personalized products and services while maintaining operational flexibility to meet changing customer demands.

2.3 Customization and Flexibility

Offer highly customized and flexible solutions to adapt to changing customer needs and provide added value.

EXAMPLE

The company offers a custom footwear design service using 3D printing. Customers can provide exact measurements of their feet and choose the design and materials to get custom-made shoes that perfectly fit their needs and style.



- **Focus on Quality:** Participants will learn how to embed quality into their business strategy, ensuring consistent delivery of superior products and services that differentiate them in the market.

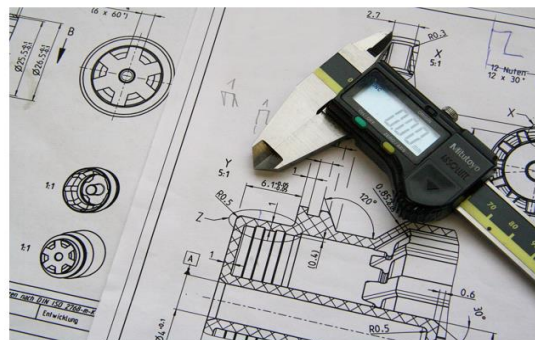
2.4 Focus on Quality

Ensure high quality standards in all products and services, along with efficient delivery times.

EXAMPLE

The company specializes in manufacturing critical aerospace components using high-precision 3D printing technology. They undergo rigorous quality testing and meet strict safety and performance standards to ensure parts meet the most demanding requirements of the aerospace industry.

Metrology
Essays
Visual inspection
...



- **Presence in Emerging Markets:** The workshop highlights strategies for entering and thriving in emerging markets, offering insights on navigating local challenges, understanding consumer behavior, and leveraging growth opportunities in these regions.

2.5 Presence in Emerging Markets

Identify and expand into emerging markets where additive manufacturing can have a significant impact, such as personalized medicine and specialized parts production.

EXAMPLE

The company is expanding into emerging markets, such as the production of customized medical prosthetics. Using 3D printing technology, they manufacture prosthetics tailored to the individual needs of patients, thereby improving the quality of life of people in these growing markets.



Through practical exercises, case studies, and strategic planning tools, this module equips participants with the skills needed to create innovative, adaptable, and high-quality business models and strategies for long-term success.

REFERENCES:

Books

1. "Business Model Generation" by Alexander Osterwalder and Yves Pigneur - A guide for visionaries, game changers, and challengers who want to learn about designing and innovating business models.
2. "Blue Ocean Strategy" by W. Chan Kim and Renée Mauborgne - Explains how to create uncontested market space and make the competition irrelevant.
3. "Lean Startup" by Eric Ries - Introduces a methodology for developing businesses and products faster and more efficiently through continuous innovation.

Articles

1. Harvard Business Review - An invaluable source of articles on strategy, innovation, and leadership.
2. "The End of Competitive Advantage" by Rita Gunther McGrath - Discusses how businesses can thrive in environments where competitive advantages are transient.

Podcasts

1. HBR IdeaCast - Offers a rich variety of topics in business, management, and strategy, presented by thought leaders in the business world.
2. Masters of Scale with Reid Hoffman - Explores how companies can grow from nothing to global impact through interviews with famous founders.

Websites

1. Forbes - Leadership Strategy - A section dedicated to business strategies and leadership.
2. Strategy+Business - Publishes in-depth articles on strategy, operations, leadership, and digital transformation.

Entrepreneurship Module 7.

TITLE OF THE MODULE: Technology and Innovation Management

LEADING ORGANIZATION: NaraXR

INSTRUCTOR: Faruk Ege ÖZEN

MAIN CONTENTS:

This module covers the essential aspects of **Technology and Innovation Management**, providing a deep dive into how technology has influenced business practices from the **Industrial Revolution** to modern-day digital transformations. Starting with a historical perspective, it explains how technological advancements like the steam engine and electricity reshaped industries, leading to significant productivity improvements. The shift from manual labor to machine-based production marked the beginning of large-scale innovation, a theme continued throughout the module.

The module also explores **innovation patterns**, explaining the five phases of technological transformation. These include early craftsmanship, the rise of factories, mass production, and the digital era, where the internet and rapid data processing transformed industries. The importance of different types of innovations is emphasized, such as **radical, incremental, supportive, and disruptive innovations**. Each type of innovation is explained in the context of product, process, and service development.

Key concepts like **social, environmental, and technological innovation** are discussed, with a focus on their impact on businesses and society. The module also delves into **innovation strategies**, analyzing leadership, followership, cost minimization, and market segmentation strategies used by businesses to maintain competitive advantage.

Lastly, the characteristics of innovative businesses and the entrepreneurial mindset are examined, providing insights into what drives innovation in modern organizations.



Innovation Patterns of Technologies

What is innovation ?

Innovation is generally a process of introducing something new and spreading it among users.

Types of Innovation:

- Radical, incremental and structural innovations,
- Supportive and disruptive innovations,
- Product-service and process innovations,
- Technological and non-technological innovations
- Social, Environmental (Ecological) Innovations.

10

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Entrepreneurship Module 8.

TITLE OF THE MODULE:

AM-Themed Entrepreneurship Examples & Hands-on Learning Examples

LEADING ORGANIZATION:

Gazi University

INSTRUCTOR:

Prof. Oguzhan Yilmaz

MAIN CONTENTS: (describe the main contents of the module (200-300 words), eventually add some figures from the presentations to better clarify the content)

This module covers examples of additive manufacturing (AM) entrepreneurship and hands-on learning tools. The module starts with the AM market trends and growth rates in the AM market covering 8 years (2020-2028) and 10 years (2022-2032) see Figure 1.

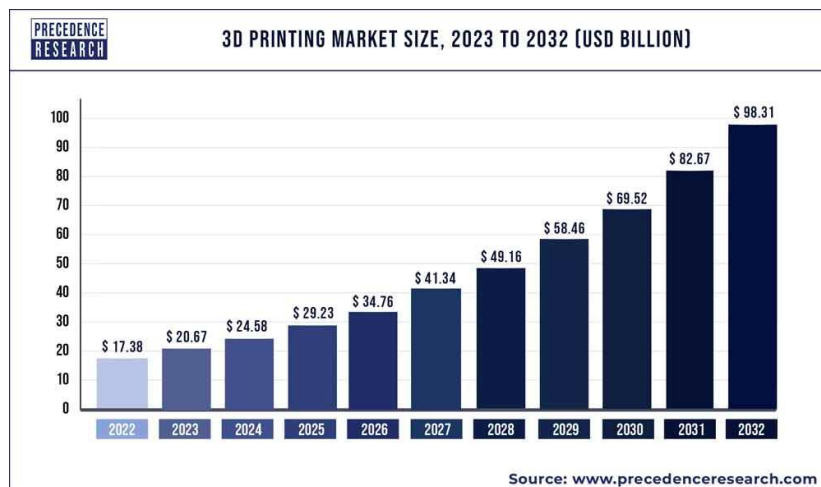
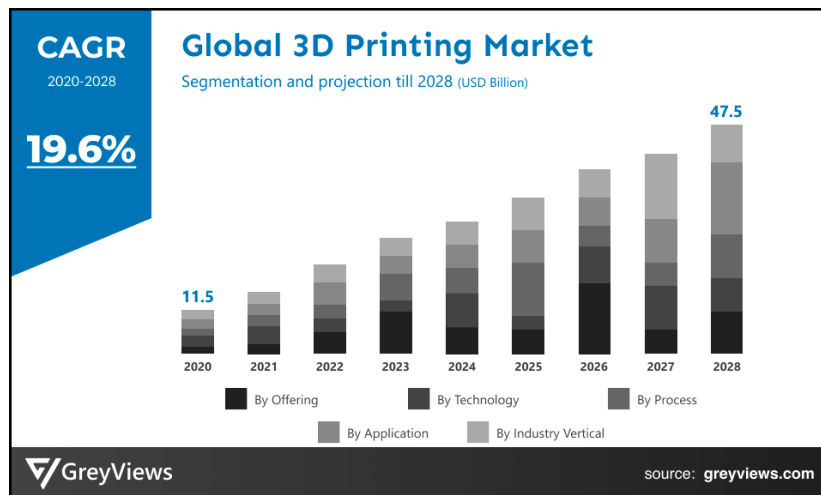


Figure 1. Global 3D Printing (Additive Manufacturing) Market Growth Rate

Technology sectors are introduced and explained in detail, which may lead the entrepreneurs see Figure 2. AM companies founded in different sectors are diversified and the landscape is given by classifying the companies as hardware, software, materials, service, post-processing, research and institutions, etc.

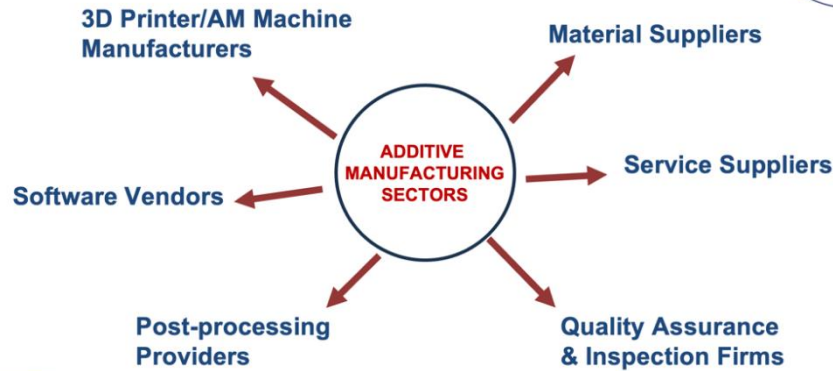


Figure 2. AM Sectors

The module continues with entrepreneurship examples from different EU countries, i.e., Türkiye, UK, Belgium, and France. These examples are prominent start-ups in different AM technologies, such as WAAM, L-PBFP, Post-processing, etc.

Hands-on learning tools can take various forms, depending on the subject and the learning objectives. This module also summarizes these tools in a broad sense. Some examples of the tools are Simulations and role-playing, interactive workshops, laboratory work, creative arts, and design projects. Online courses and the popular platforms that give these courses are introduced in this module. Social media, particularly the websites that play videos, serve as critical steps in learning. Some of the YouTube channels are given as an example. Some Eu countries have established Maker Spaces and Fab Labs and names, scope, and location of these labs are introduced as well. Figure 3 shows a Fab-lab view.

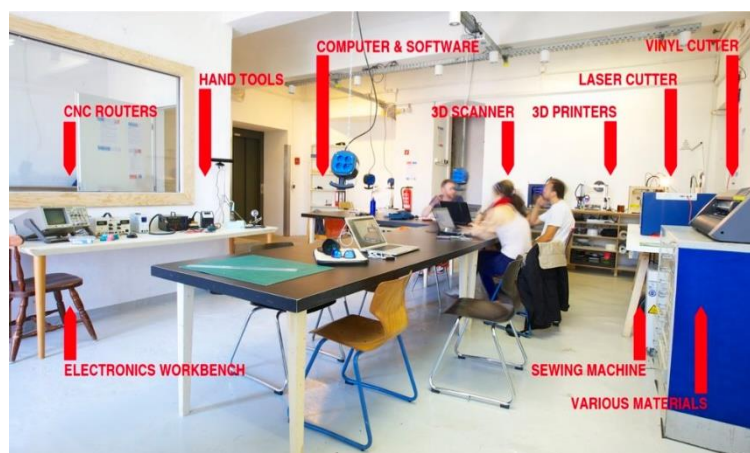


Figure 3. A fab-lab picture

Most AM Technologies uses software, and there are plenty of open-source software, and dedicated software available in the market. This module also mentions the possible software packages and their abilities in AM activities. In learning activities, competitions and hackathons play a critical role for motivating the younger generations. The list of these organizations are given in the module. Finally, the module summarizes the published books in AM and community forums that allow AM users to interact each other.

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