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METALS: MachinE Tool Alliance for Skills

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Acronyms & Abbreviations

3D	Three-dimensional
AM	Additive Manufacturing
ABS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
D	Deliverable
EQF	European qualification framework
FDM	fused deposition modeling
HIP	Hot isostatic pressing
LMD	Laser metal deposition
LO	Learning outcome
LU	Learning Unit
PC	Polycarbonate
PLA	Poly Lactic Acid
SLM	Selective Laser Melting
CECIMO	European Association of the Machine Tool Industries
SLS	Selective Laser Sintering
STL	Stereolithography
VDW	German Machine Tool Builders' Association

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1. Introduction

This D.4.2 curriculum builds upon the earlier WP2 findings, experiences within content development in METALS, and feedback from internal and external experts as well as from the learners that participated in the piloting phase (cp. deliverable 5.1). It consists of 27 (26 in English version due to “English for AM-unit”) Learning Units (LUs) divided along three main knowledge areas: work process-oriented area, AM-specific area and entrepreneurship-oriented area. Modelled around Learning Outcomes (LO), the curriculum offers a comprehensive approach to training. It covers both technical and soft skills needs in 3D printing, otherwise known as Additive Manufacturing, and is targeted for knowledge and skills needs at EQF level 5. Partners selected this EQF level with a view to provide a common ground between skilled workers and advanced apprentices.

The estimated time for the completion of each unit is indicatively of one hour.

2. METALS curriculum: Work process-oriented units

A. Acquire

Applying content of LU client orientation and LU marketing to the AM field:

At the end of this unit participants will be able to:

- a) Offer Additive Manufacturing (AM) services
- b) Serve a corresponding range of products
- c) Advise potential customers
- d) Analyse customer demands
- e) Look for and offer alternative solutions
- f) Negotiate smartly
- g) Analyse the terms and conditions for a successful fulfilment of orders
- h) Estimate approximate costs
- i) Prepare and give proposals to potential customers
- j) Produce an order draft

B. Contracting

Using content of LU entrepreneurship basics for proper and legally effective contracting.

At the end of this unit participants will be able to:

- a) Work customer oriented
- b) Complete a preliminary offer
- c) Estimate costs
- d) Work on a concrete draft
- e) Apply standard computer software
- f) Negotiate smartly

C. Sketching

Applying content of LU 3D printing to the concrete product chosen.

At the end of this unit participants will be able to:

- a) Name in detail the features of the product and its functions
- b) Choose the materials which suit the features demanded

- c) Understand the guidelines for the design and apply them
- d) Provide a freehand sketch of the product to be manufactured
- e) Apply standard computer software

D. CAD

Applying content of LU AM design principles to the concrete product.

At the end of this unit participants will be able to:

- a) Use CAD software target-oriented and efficiently
- b) Analyse and optimize a construction design
- c) Define file formats and converting them into various formats

E. CURA basics:

Applying content of LU Processing/CAM within a concrete software.

This learning unit consists of following chapters:

- a) Overview of "Cura"
- b) Opening the desired 3D-model
- c) Analysing the 3D-model
- d) Manipulating the 3D-model
- e) Duplicating the 3D-model
- f) Movement of one model
- g) Checking the 3D-models
- h) Conclusion of the 3D-model manipulation
- i) 3D printer settings
- j) Final overview

F. CURA advanced:

Applying content of LU Processing/CAM to a concrete printer.

At the end of this unit participants will be able to:

- a) Understand the different possibilities and the assignments
- b) Set up the printer to make it work faster and with good quality

G. Printing

Applying content of LU 3D printing to a printer.

At the end of this learning unit participants will know how to prepare and print a 3D-model.

This process is divided into five steps starting with preparing the printer and material and ending with the post-processing of the print. The content is structured in 6 chapters:

- a) Tools and materials needed
- b) Print settings in Cura
- c) Preparing the filament and printer
- d) Starting the print / adjusting print-settings
- e) Postprocessing the print
- f) Observing safety regulations

H. Troubleshooting

At the end of this unit participants will be able to avoid:

- a) The print not sticking to the bed
- b) Not extruding enough plastic
- c) Layer separation and splitting
- d) Warping

I. Maintenance

Applying content of LU Post-processing to a concrete printer.

At the end of this unit participants will be able to perform the following basic maintenance operations:

- a) Clean the printer
- b) Update the firmware
- c) Build plate calibration
- d) Lubricate the axles
- e) Check for play on axles
- f) Check tension of short belts
- g) Lubricate the lead screw of the Z motor
- h) Retighten the hot-end isolator

J. Completion

Applying content of LU client orientation and LU entrepreneurship basics to complete the project and for further projects.

At the end of this unit participants will be able to:

- a) Carry out post-calculations
- b) Prepare and dispatch the invoice
- c) Deliver the product
- d) Track receipt of payment
- e) Quality management
- f) Analyse and reflect on lessons already learnt.

3. METALS curriculum: AM units

1. Additive Manufacturing (general)

This LU introduces the main features of 3D-printing (or Additive Manufacturing) technologies. It aims to teach participants how and why these technologies are finding different industrial application areas. As additive machine makers have given several names to these technologies, it also aims to teach participants how to classify them.

At the end of this unit participants will be able to:

- a) Define the technologies
- b) Explain the background
- c) Classify the processes: mention the types of technologies
- d) List advantages and disadvantages
- e) Explain the applications
- f) Indicate challenges and opportunities. State of the technology

2. Additive Manufacturing (specific)

This LU focuses on the main technologies used and their specific features.

At the end of this unit participants will be able to:

- a) Sort out the technologies selected for this course:
 - Powder Bed Fusion: SLS, SLM and EBM
 - Directed Energy Deposition: LMD
 - Material Jetting: Polyjet
- b) Explain the processes in the selected technologies

3. 3D Printing

This LU provides practical knowledge to help participants in producing a 3D-printed part for the first time.

This learning unit is organised in the following chapters:

- a) What does 3D Printing stand for?

- b) The different types of 3D Printers
- c) The characteristics of the layer
- d) The structure of a printing machine
- e) Filaments and materials
- f) The Maker Culture – low cost
- g) Experiment with STL – Stereolithography
- h) Repositories of parts on internet: Thingiverse, GrabCAD..

4. Material sciences (metals)

This LU explains which materials (metals) are used in 3D printing and which properties are needed to suit the technology and its application.

At the end of this unit participants will be able to:

- a) Distinguish between the different types of metals used in Additive Manufacturing.
- b) Select the different formats of these materials.
- c) Identify the different properties of each material.
- d) Select the application fields according to the specific Additive Manufacturing technologies.
- e) Know about the necessity of recycling materials and its issues.
- f) Observe safety standards in the handling and treatment of metals.

5. Material sciences (non-metals)

This LU explains which materials (non- metals) are used in 3D printing and which properties are needed to suit the technology and its application.

At the end of this unit participants will be able to:

- a) Distinguish between the different types of non-metal materials: plastics, composites, rubber, etc.
- b) Estimate the characteristics of new materials and new combinations of materials.
- c) Select states and formats: liquid resins, powder and filaments.
- d) Apply the required conditions for storage and treatment of non-metal materials.

6. Design principles for AM

The possibility of designing very complex structures is one of the biggest benefits of 3D printing. This LU gives an overview of design in 3D-printing and how it impacts on the product designing process.

At the end of this unit participants will be able to:

- a) Describe the design principles for 3D printing
- b) Identify the concepts of freedom of design, organic forms and topological optimization
- c) Understand the new concepts brought by 3D printing into engineering: design possibilities, features of the process and growing manufacturing
- d) Distinguish between open source and proprietary software for design
- e) Obtain a digital file of a part: draw, download a 3D model from a repository, digitalize an existing physical model

7. Processing - CAM

The digital files must undergo a transformation process before being suitable for AM. The process (the software) varies according to the specific technology.

At the end of this unit participants will be able to:

- a) Transform the digital file to adapt it to the specific manufacturing process.
- b) Know what different parameters to choose in CAM programs and distinguish the effect of each one in the corresponding processes for:
- c) Material Extrusion: FDM
- d) Powder Bed Fusion: SLS and SLM
- e) Direct Energy Deposition: LMD
- f) Material Jetting: Polyjet
- g) Assess different positioning options and determine the support material needed

8. Reverse engineering

At the end of this learning unit participants will know what reverse engineering is, know about different types of scanners and software and about some possible applications.

This learning unit is organized in the following chapters:

- a) Perform the Reverse Engineering process
- b) Description of the Reverse Engineering process

- c) Scanner and software selection for the scanning process
- d) Characteristics of the digitalized files
- e) Experiment with different applications

9. Post-processing and final operations

Sometimes the parts produced are not ready for use at the end of the AM process. They still need to go through some other additional processes. Some final operations must also be performed. This LU delivers more in-depth information on these aspects.

At the end of this learning unit participants will have a basic understanding of the main post-processing techniques.

This learning unit is organized in the following chapters:

- a) Introduction
- b) Material requirements, tolerances and surface finish
- c) Design thinking about post-processing
- d) Emptying confined areas
- e) Removal of supports
- f) Machining processes - thickness oversized
- g) Cutting the base plate
- h) Grit blasting
- i) Residual stresses - heat treatment
- j) Hot Isostatic Pressing (HIT)
- k) Production flow

4. METALS Curriculum: entrepreneurship units

I. Communication skills client oriented

Communication is the process of sharing information, thoughts and feelings between people through speaking, writing or body language. Effective communication aims to generate a message that is received and understood correctly.

At the end of this learning unit, participants will be able to recognize the crucial aspects of:

- a) Effective written communication
- b) Effective verbal communication
- c) Effective non-verbal communications
- d) Active listening
- e) Effective phone / skype communication
- f) Basis of public speaking
- g) Digital skills for communication
- h) Client-orientated communication

II. Leadership and project management

Leadership is the activity of leading a group of people or an organization and the ability to do this finalizing all activities in line with specific goals. Project management is the application of knowledge, skills, tools and techniques to lead activities to meet a project's goals and requirements.

At the end of the unit, participants will be able to recognize the crucial aspects of:

- a) Efficient team leadership
- b) Possible leadership approaches
- c) Activation of a decision-making process
- d) Facilitation of group discussion
- e) Dealing with conflicts
- f) Leadership and teambuilding

III. Problem setting and problem solving

Understanding the critical components involved in problem-solving will help is an essential skill to all jobs and situations

At the end of the unit, participants will be able to recognize the crucial aspects of:

- a) The problem-solving process
- b) Defining the problem
- c) Generating alternatives
- d) Evaluating and selecting alternatives
- e) The implementation of possible solutions
- f) Lateral thinking - analytic approach
- g) Lateral thinking – holistic / systemic approach

IV. English for Additive Manufacturing [Available only in DE, IT, and ES versions of the e-learnings]

At the end of the unit, participants will be able to recognize and use effectively the main English Glossary about Additive Manufacturing.

This learning unit is organized in the following chapters:

- a) AM technologies
- b) AM materials terms
- c) AM generic terms (linked to AM industry or AM machine itself)
- d) AM process chain terms
- e) AM-related regulations terms

V. Entrepreneurship basics and organisation of a (small) company

Entrepreneurship is the act of setting out on your own and starting a business instead of working for someone else in his business.

At the end of the unit, participants will be able to recognize the crucial aspects of:

- a) The approach to provide innovative solution / products
- b) The AM business market
- c) The AM business network
- d) An innovative business strategy
- e) The draft structure of a business plan
- f) Risk evaluation
- g) The main steps of human resources management

VI. Marketing

Marketing is the management process through which goods/services move from concept to the customer. It is creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society.

At the end of the unit, participants will be able to recognize the crucial aspects of:

- a) Marketing as professional communication
- b) The definition of the client target groups
- c) Customer relationship management
- d) Stress management
- e) Digital marketing
- f) Differences of classic marketing vs social media strategy

VII. E-commerce

E-Commerce is the transaction of buying or selling online. Electronic commerce draws on technologies such as mobile commerce, electronic funds transfer, Internet marketing, online transaction processing and others.

This learning unit provides information about all basic elements of e-commerce:

- a) Business application and advantages
- b) Trends
- c) Impact on markets
- d) Social impact
- e) Examples related to the Additive Manufacturing sector

VIII. Business Regulation and Law

In Europe clear business regulation has been defined in several areas. It is important to know the applicable legislation and (even more) to understand where to find correct and updated information.

At the end of the unit, participants will be able to recognize some important aspects regarding:

- CE marking
- Additive Manufacturing and the EU Machinery Directive

- Elements and aims of the EU Machinery Directive
- Start up and business in Additive Manufacturing
- Available funds and exchange programmes for entrepreneurs