DEMO or DIE

Develop Engaging Massive Open Online Resources for Designers Innovative Education

3D Printing Design and Operation Learning Units (Short Version)

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Contents

1. 3D Printing Design and Operations Training Programme

The 3D Printing Design and Operations curriculum is designed for increasing or developing the target groups competences in terms of general knowledge of 3D Printing, Design and Operation of desktop 3D Printers. The curricula is covering topics such as design rules, materials characteristics, process applicability, among other topics, considered as relevant to increase or develop general knowledge of 3D Printing, Design and Operation of desktop 3D Printers.

The expected learning outcomes are described in two ways: course generic outcome descriptors organized in knowledge, skills, autonomy and responsibility (see Section *Course general description);* and in detail for each competence unit (see Section *3. Competence units / Units of learning outcomes)*, organized in knowledge and skills corresponding to a **basic proficiency level** within EWF´s Systems Framework levels (see *Appendix),* in alignment with the European Qualification Framework (EQF level 3). The course/curriculum is organized according to five Competence Units (CU) / Units of Learning Outcomes (ULOs), as shown in Table 1:

COMPETENCE UNITS / UNITS OF LOs	Recommended Contact Hours*	Expected Workload**
CU A_ 3D Printing Material Extrusion (MEX) Overview	3.5	7
CU B _ Introduction to CAD (Optional)	3.5	7
CU C _ Design for Material Extrusion MEX	3.5	7
CU D _ 3D Printer Operation and Practical Applications	3.5	7
CU E _3D Printing Project “Do it Yourself”	3.5	7
TOTAL	**17.5**	**35**

Table 1 -Structure of the 3D Printing Design and Operations Training Programme

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

2. Course general description

In this section the 3D Printing Design and Operation Learning Units are described in a generic way using the EQF descriptors defined in terms of knowledge, skills, autonomy and responsibility.

COURSE / TRAINING PROGRAMME in **Material Extrusion 3D Printing Design and Operations**			
EWF Level	**Knowledge**	**Skills**	**Autonomy & Responsibility**
Basic	Basic facts, principles and general concepts of design for material extrusion polymer 3D printing process.	Be able to create 3D CAD models, prepare for the print process, execute the printing process as well as the post-processing and to undertake basic troubleshooting of material extrusion polymer 3D printers and printed parts.	Work under supervision, taking personal responsibility for own actions and for the quality and accuracy of the work produced.

Table 2 - Course general outcomes descriptors

3. Competence units / Units of learning outcomes

For each CU/ULOs objectives and scope are defined for a specific depth of knowledge and skills. Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical workshop training (C), etc., as shown in the following example:

Contact Hours sub-division: A + B + C		
A	**B**	**C**
Theoretical content Provided through: Classroom teaching / Slides Presentation. etc	**Practical application** Provided through assigned projects/exercise. etc.	**Practical application** practical workshop /LABs. etc.

The detailed description of the four CUs is given onwards:

CU A_3D Printing Material Extrusion (MEX) Overview	**RECOMENDED CONTACT HOURS**
SUBJECT TITLE	
MEX Process Overview	2
Overview on Polymer Materials, their properties and applications	1.5
Total	**3,5**
WORKLOAD	**7**

LEARNING OUTCOMES –3D Material Extrusion (MEX) Overview	
KNOWLEDGE	Basic factual knowledge of: – Material Extrusion (MEX) process – Polymer Materials and characteristics and their effects on MEX 3D printing – Potential and limitations of Polymer MEX materials – Real life applications for MEX, including in the biomedical sector

LEARNING OUTCOMES –3D Material Extrusion (MEX) Overview	
SKILLS	Distinguish 3D Printing parts produced by MEX from other polymers 3D printing processes List the advantages and limitations of MEX over other 3D Printing Polymers processes, including its applicability according to the characteristics of the process Identify Polymer Materials for MEX 3D Printing use according to real-life applications' requirements Recognize examples of MEX in real life applications, including in the biomedical sector.

CU B_Introduction to CAD SUBJECT TITLE	RECOMENDED CONTACT HOURS
Fundamentals of Computer-Aided-Design	0.5
Introduction to 3D CAD Software	1
Solid Modelling	1.5
Preparing for 3D Print – File Formats	0.5
Total	**3.5**
WORKLOAD	**7**

LEARNING OUTCOMES – Introduction to CAD	
KNOWLEDGE	Basic factual knowledge of: – 3D CAD design and modelling process – 3D solids and assemblies – File Preparation for 3D Printing
SKILLS	Navigate the interface of a standard CAD software to view in the 3D space the models/or existing ones. Manipulate objects in a 3D space by zooming in, zooming out and rotating the view. Design simple solid shapes and combine them to form an assembly. Create assemblies of 3D objects to make a final 3D model. Save and export files ready for 3D Printing.

CU C_Design for MEX SUBJECT TITLE	RECOMENDED CONTACT HOURS
Think Additively	0.5
Material Extrusion Overview	1.0
Design Principles/Specific Design Considerations	1.5
Slicing and Print Preparation	0.5
Total	**3.5**
WORKLOAD	**7**

LEARNING OUTCOMES – Design for 3D MEX	
KNOWLEDGE	Basic factual knowledge of: – 3D Design Thinking – Design Principles for MEX – Capabilities and limitations of process and influence on design – Design considerations for MEX polymers part – Slicing and Print Preparation
SKILLS	Apply design for Material Extrusion principles when developing and CAD modelling a part Associate design considerations to design thinking in the development of AM Polymer parts Recognise MEX 3D Printing potentials and limitations when designing AM Polymers parts Relate the capabilities and limitations of MEX to basic design considerations Provide solution-based approaches to redefine simple design problems

CU D_3D Printer Operation and practical applications SUBJECT TITLE	RECOMENDED CONTACT HOURS
3D printing operational settings	0.5
Post processing for polymers	1.5
Trouble shooting	1.5
Total	**3.5**
WORKLOAD	**7**

LEARNING OUTCOMES – 3D Printer Operation and practical applications	
KNOWLEDGE	Basic factual knowledge of: – 3D Printing operational settings – Post processing methods for polymers (Cleaning and support removal, surface smoothing and coating operations) – 3D printing problem solving
SKILLS	Set up a 3D printer by following all the operational steps required. Recognise the required Health Safety and Environmental measures linked to MEX 3D printing process. Recognise the need for post processing operations on as-built parts according to the required part properties. Recognise the requirements that 3D parts need to comply with for each post process. Choose post-processing methods for a variety of part geometries, materials MEX, in order to improve surface properties such as roughness, chemical and/or physical resistance, haptics & colour. Solve basic problems identified when printing a part for MEX.

CU E_3D Printing project "Do it Yourself"	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
3D printing project "Do it yourself"	3.5
Total	**3.5**
WORKLOAD	**7**

LEARNING OUTCOMES –3D Printing project "Do it Yourself"	
KNOWLEDGE	Basic factual knowledge of: - Developing an 3D printing project using MEX
SKILLS	Design the part and create a 3D model file using CAD software. Export STL file format to open in slicing program for 3D Printing. Select the appropriate build parameters, printer settings, material, and temperature settings in a Slicing software Set up a 3D printer by following all the operational steps required. Recognise the post-processing operations to be applied on as-built parts according to the required part properties. Solve basic problems when printing a part for MEX, if needed

4. Participation and entry requirements

The Online Material Extrusion 3D Printing Design and Operations Course targets both **Students** from Vocational Education and Training (**VET**), aging above 16 years, and from Higher Education (**HE**).

Also, **Non-Manufacturing Personnel**, such as P**rofessionals** from the Health and Artistic sectors (e.g. archaeologists, architects, etc.) can participate in the course.

5. Learning Path

The Online Material Extrusion 3D Printing Design and Operations Course is recommended to start with "3D Printer Operation and Practical Applications" from CU_D, followed by any other CU as they are independent and as the assessment of the learning outcomes is foreseen at the end of each CU through the "assessment point".

CU_B is optional for students with existing knowledge and skills on CAD. After completing the full set of CUs (CU A, C and D), students can take part of CU_E, which refers to creating a 3D model file with the option of printing it. The course is completed after the delivery and approval of the final project "Do it Yourself". The learning path is illustrated in Figure 1.

The "assessment point" corresponds to a summative assessment using multiple-choice questions format which are applied after the attendance and completion of the training course for each CU. The number of questions are equal to the recommended number of contact hours. (I.e., number of contact hours= 14, number of questions= 14). For CUs lasting seven contact hours, students will respond to seven questions

The Material Extrusion 3D Printing Design and Operations course has three options for its implementation; fully online, fully face to face or blended. Students can complete training by choosing one of these three options. Whichever option is selected, students can follow the path showing in Figure 1.

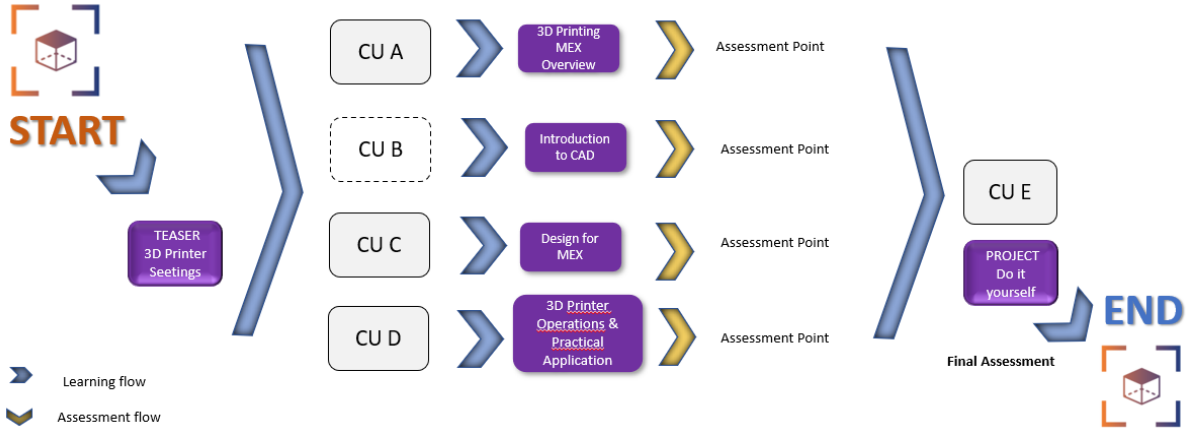

Figure 1 - DEMO or DIE learning path

6. Software Resources for Students

In order to take full advantage of the course and learning experience, the following software resources are recommended to students:

- Internet browser
- CAD software (e.g. FreeCAD, TinkerCAD and others). A recommended user-friendly and free software would be TinkerCAD .
- 3D Printing slicer (e.g. CURA, Slic3r (free Prusa Edition) and others).

Although the listed CAD software (FreeCAD, TinkerCAD, Solid Edge, etc.) is suggested, the Learning Outcomes (for example in CU-B) can still be applicable to other software platforms.

7. Resources for Trainers and Facilitators

This section documents and lists the recommended IT and equipment resources as well as the training materials that are available for trainers and facilitators to deliver the course.

DoD project has developed several Open Educational Resources (OERs) that help trainers in the design of their lessons and learning activities. Those OERs refer to:

- **Moodle Platform**: The Online Material Extrusion 3D Printing Design and Operations Course's learning activities and assessment tools, are integrated into the Moodle platform. https://demoordieproject.eu//learningplatform.html
-
- **Online materials / resources**: The Online Material Extrusion 3D Printing Design and Operations Course has downloadable presentations and reading sources https://demoordieproject.eu/img/resources/DOD%20-%20Article_1.pdf

- **Videos:** Short videos provide brief information about each competence units. https://demoordieproject.eu/resources.html

- **TikTok**: Short-form videos raising awareness on 3D Printing, spotting key words. https://www.tiktok.com/@demodie

- **Game Space (mission):** A game is an optional feature, showing the potential use of 3D printing in an interactive and funny way, among others. https://demoordieproject.eu/space-game.html

- **Guideline for inclusive teaching**: The guideline is a framework to integrate inclusive strategies and useful alternatives that can support all learners (https://demoordieproject.eu/img/resources/Guideline%20for%20inclusive%20teaching.pdf)

- **TinkerCAD:** TinkerCAD is a free software that is used to design 3D models. It is approached in CU_B and suggested as tool to develop the 3D Printing Project "Do it Yourself" in CU_E. https://www.tinkercad.com

Additionally, the five competence units follow the Articulate Storyline available in the online platform (e.g. moodle). The Articulate Storyline courses have interactive and interesting features, such as:

- **Mobile Player/Responsive View:** The mobile version adapts course content for any device and various screen sizes. The player automatically adjusts its controls intuitively, giving students on the go the seamless and responsive experience they need to meet their objectives;

- **Built-in closed captioning option:** In order for an e-learning course to be truly effective it needs to be accessible to all members of its audience. Storyline supports closed captioning files to be uploaded in association with any video or audio snippets. This is helpful not only to learners with a hearing impairment, but also helps learners at the most inopportune times, such as forgetting their headphones, or unconventional/ inconvenient locations like on public transportation or in a noisy office

- **Publish courses with HTML5 performance**

- **Intuitive User Interface**

In this context is important to consider the following principles *[1] when designing online course and learning activities:

- **Simplify:** Avoid adding elements and information that can lead to information overload. Keep the design clean and simple and reduce clutter as much as possible.
- **Break it Up:** By breaking the content into smaller, more digestible pieces of material, so learners can better retain important information.

[1] ***Cognitive Load Theory (****Richard Atkinson and Richard Shiffrin, 1968)*

8. General recommendations

Some general recommendations for implementation are given in this section in order to ensure that Material Extrusion 3D Printing Design and Operations course is a more effective training and learning experience according to the different contexts: online, blended and face to face (presential). The table below summarizes the main ideas:

<table>
<tr><th colspan="2">RESOURCES AND TOOLS</th><th colspan="3">RECOMMENDATION</th></tr>
<tr><th>List</th><th>Description</th><th>Online</th><th>Blended</th><th>Presential</th></tr>
<tr><td>Slides presentation</td><td>Available as learning experience in the moodle platform and downloadable from the project website.</td><td rowspan="3">Students are recommended to follow the given learning pathways (page 13 of this Guideline) according to their needs and interests</td><td colspan="2">Recommended adaption by:
redesigning the materials based on the students age, academic and technical background
reducing the amount of text per slide
selecting and giving context to the videos
removing the formative assessment or replacing them by Q&A;
increasing the number of practical examples.</td></tr>
<tr><td>Case study /Project</td><td>CU E is referring to the case study/project</td><td colspan="2">Different interactions with the case study are recommended to stimulate the autonomy and creativity of the students, namely by:
adding levels of difficulties to the case study
selecting the part to be designed and printed
having case studies developed by small groups.</td></tr>
<tr><td>Delivering training</td><td>The implementation of theoretical and practical components of the course</td><td colspan="2">Recommendations for delivering the training by:
introducing Q&A at the middle and end of each CU session
demonstrating physical parts and hardware rather than just seeing images
adjusting the contact hours based on the students age, academic and technical background
combining as much as possible a practical and</td></tr>
</table>

			theoretical approach during the session (e.g. printing a part with defects and analyse the problem shotting in CU D)
Assessment point (Multiple choice)	Displayed as written exam in moodle platform and by the organisation or body responsible for the assessment.		It is recommended that the responsible organisation supervises the assessment by: • providing the access to the multiple choice questions, either through a link or paper format. • applying or incorporating additional alternative assessment methods (I.e essay/ case studies), • using formative assessment.

9. Appendix

Additive Manufacturing (3D Printing) System Framework

ADDITIVE MANUFACTURING FRAMEWORK			EQF Level
KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY	
Knowledge at the most advanced frontier in the field of additive manufacturing and at the interface between other manufacturing fields.	Highly advanced and specialised skills and techniques, including synthesis and evaluation required to solve critical problems in research and/or innovation applied in additive manufacturing technology. Extend and redefine existing knowledge or professional practice when applying additive manufacturing processes.	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes including research at the forefront of additive manufacturing.	8
Highly specialised and forefront knowledge including original thinking, research and critical assessment of theory, principles and applicability of additive manufacturing processes.	Highly specialised problem- solving skills including critical and original evaluation, allowing to define or develop the best technical and economical solutions, when applying additive manufacturing processes, in complex and unpredictable conditions	Manage and transform additive manufacturing processes in a highly complex context. Fully responsible for the definition and revision of additive manufacturing personnel's tasks.	7
Advanced knowledge and critical understanding of the theory, principles and applicability of additive manufacturing processes.	Advanced problem-solving skills including critical evaluation, allowing to choose the proper technical and economical solutions, when applying additive manufacturing processes, in complex and unpredictable conditions	Manage the applications of additive manufacturing processes in a highly complex context. Act autonomously in decision making and definition in the definition of the additive manufacturing personnel's tasks.	6
Specialised, factual and theoretical of theory, principles and applicability of additive manufacturing processes	Specialised range of cognitive and practical skills, allowing to develop solutions or choose the appropriate methods, when applying additive manufacturing processes in common/regular problems.	Manage and supervise common or standard additive manufacturing processes, in an unpredictable context. Take responsibility in standard work and supervise additive manufacturing personnel's tasks.	5
Factual and broad concepts in the field of additive manufacturing processes.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific additive manufacturing problems.	Self-manage of professional activities and simple standard applications of additive manufacturing processes in predictable contexts but subject to change. Supervise routine tasks and similar function workers, as well as take responsibility for decision making in basic work.	4
Knowledge of facts, principles, processes and general concepts in the field of additive manufacturing.	Basic cognitive and practical skills required to use relevant information in order to carry out tasks and to solve routine problems using simple rules and tools in additive manufacturing applications.	Take responsibility for completion of tasks in additive manufacturing applications. Adapt own behaviour to circumstances in solving problems.	3
Basic factual knowledge in the field of additive manufacturing	Basic range of cognitive and practical skills required to accomplish tasks and solve problems by selecting and applying methods, tools, materials and information in the field of additive manufacturing.	Carry out, under supervision, professional activities in additive manufacturing applications with some autonomy.	2
Basic general knowledge in the field of additive manufacturing technology.	Basic skills required to carry out simple tasks related with additive manufacturing.	Perform basic tasks related with additive manufacturing technology under direct supervision in a structured context.	1