  

ShakeAM

sharing knowledge in design for AM

SHARING KNOWLEDGE IN DESIGN FOR AM

SHAKE AM Training Methodology

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Contents

1. Background

Education and the growth of human capital are crucial in reinforcing Europe's competitiveness in manufacturing. The need for certified and highly skilled workers has already been recognised by several industrial companies, industrial associations and policy makers throughout the world, encouraging a shift towards innovation and advanced manufacturing techniques as one of the most important drivers of global manufacturing competitiveness. Additive Manufacturing (AM) is one of the booming technologies that plays a vital role in reindustrialisation. The requirements and characteristics of Design for Additive Manufacturing (DfAM) are constantly changing in response to the expanded growth and broad use of Additive Manufacturing (AM) technology. ShakeAM addresses this need to increase the capacity and readiness of Higher Education (HE) institutions. To help teachers and other teaching professionals improve their skills and be able to impart them to their students, ShakeAM will assist them in becoming familiar with digital pedagogy/digital education subjects. Through the DfAM Digital Ecosystem and related approaches, a new strategy for training professionals will be implemented, one that encourages lifelong learning by keeping professionals involved and sharing information with younger students.

2. The ShakeAM Project

Experienced designers are desperately needed because the Design for AM (DfAM) methodology is the initial step in creating AM products with added value. Therefore, in order for businesses to properly use additive manufacturing technology and to guarantee that engineering design solutions are produced "first time right," AM profiles with design expertise are essential. To fill the talent gap, new educational initiatives are needed. These professionals must be proficient in computer-aided design, simulation, parametric modelling, and other cutting-edge tools like artificial intelligence, generative design, and topology optimisation. Due to the continuous and rapid advancement of AM technology, which happens quicker than traditional qualification or re-qualification of workers can offer, it is vital to impart state-of-the-art knowledge to end users as well as to those joining the workforce. A well-designed product also makes sure that the "Total Design" principles, which include sustainability, operational use, service life, repair, and end-of-life, are considered. These components will directly support the EU's strategy to achieve Twin Transition, which is essential to implementing a circular business model and reducing waste.

The goal of ShakeAM is to fill this significant vacuum while fostering the interchange of best practises in AM Design. To that end, a specialised DfAM Digital Ecosystem and a Design Best Practise Database are being developed with HE institutions and students in mind. This ecosystem will have a significant and lasting impact on HE institutions' capacity and readiness to manage an efficient shift towards digital technologies for a systematic approach regarding training delivery, one that will ultimately benefit HE students for the rest of their lives and encourage their active participation in the learning process. With the use of cutting-edge teaching tools, pedagogical techniques, and methodologies, ShakeAM will promote the rehabilitation of numerous industrial ecosystems in Europe.

3. Target Groups

ShakeAM tackles the need to increase the capacity and readiness of Higher Education (HE) institutions to manage an effective shift towards digital technologies for a systematic approach regarding the training delivery and acquisition of digital skills and competences on Design for Additive Manufacturing (DfAM) by HE students and VET students (including those from disadvantaged backgrounds, learners with Special Educational Needs and Disabilities (SEND) as well as female students) and designer professionals (AM and non-AM experienced). ShakeAM will also support teachers and general teaching professionals becoming familiar with digital pedagogy/digital education contents, and with the latest best practices, improving their competences and being able to transfer them to their students.

3.1. Users

ShakeAM will target the following audiences to enrol in the DfAM course or be part of the digital ecosystem:

- HE/HND Students – Engineers or other students currently obtaining a degree or diploma to work as an AM designer or transitioning from education to the labour market. They are the prime target group of the ShakeAM project and will gain the required DfAM workforce's skills according to sectoral and national needs.
- SEND Students – ShakeAM will enable Students in Higher Education or tertiary education from disadvantaged backgrounds and learners with Special Educational Needs and Disabilities (SEND) to participate in the educational courses, with both teaching and assessment material adapted to their specific needs.
- VET – Professionals with a VET background that are currently employed or want to transition to a designer for AM role. They will be able to gain new technology-related skills (AM) and be able to cope with the constant changes in AM and DfAM.
- DfAM Professionals - Professionals, from commercial and non-commercial organisations in the private sector, are going to be invited to get engaged in the digital ecosystem, both as learners and active participants in the online platform, getting access to the latest best practises, mutually exchanging knowledge and also transferring knowledge to young students/other participants.
- Other – audiences with a keen interest in Additive Manufacturing and lifelong learning attitude, e.g., young adults involved in a robotics group, STEM educators and other would benefit from participating both in the courses and the online platforms.

Participants should have a strong interest in AM, with a basic understanding of engineering principles, Computer aided design and be familiar with the fundamentals of Additive Manufacturing Technologies. In case of not possessing the above knowledge, students will be directed to introductory courses and best practices, developed by other initiatives to gain the necessary skills to be able to follow the ShakeAM training course. Moreover, learners should have access to a PC compatible with present CAD software and browsers. Student licences for using advanced CAD software and other tools will be pursued and provided by the consortium to learners in order to be able to tackle the practical exercises of the course.

3.2. The Trainers

ShakeAM will support teachers and general teaching professionals becoming familiar with digital pedagogy/digital education contents, and with the latest best practices, improving their competences and being able to transfer them to their students in tandem with inclusive teaching guidelines. ShakeAM aims to involve experienced trainers in capacitating new trainers who have less training experience with both digital education and AM processes and will create a pool of qualified instructors who can later impart the knowledge to others. This will be achieved through the two train the trainers' sessions, which will first capacitate trainers belonging to the partner institutions in terms both the content developed and using the DfAM digital ecosystem and can later include trainers from other institutions or associated partners.

4. Training Methodology

The novel ShakeAM training methodology will strive to create a DfAM digital ecosystem of interlinked functional areas, that can serve as an impartial “one-stop shop” for AM design in Europe. This ecosystem will both contribute to the overall digital transformation of HE institutions and it will enable knowledge transfer to VET and Adult Education institutions, as well as individual learners. The aspects that make the ShakeAM training methodology and ecosystem innovative are:

Dynamic Syllabus: State-of-the-art literature will be combined with industry guidelines and current practices to ensure a dynamic syllabus capable of responding to the constantly evolving technological landscape as well as emerging practices in AM technology.

a. Micro-learning: Bit sized material allows learners to choose the amount of content they wish to study based on their available time, with a view of completing the learning outcomes of each Competence Unit in a convenient and time effective way.
b. Up to date “Best Practices Database”: Curriculum is linked to AM community through active connection with stakeholders, association groups and other projects. Success stories and best practices from the industry will populate a “Best Practices Database”, that will be in line with all the newest developments in the field of DfAM.
c. Inclusive Teaching: embedded inclusive teaching into the structure of the course ensuring proper mechanisms through guidelines for inclusive teaching methods to support those with a disadvantaged background, special educational needs and/or disabilities. By using digital tools as an enabler and as a skill equalizer for these students, ShakeAM will capacitate and empower them to ensure that they will fully benefit from the training program and resources.
d. Actively Engagement of Students: students can interact with each other, trainers and industry practitioners using the ShakeAM sphere and forum, that will act as a meeting point, where all networking, collaboration and information sharing can take place, including documents and designs.

A competence unit focusing on advanced concepts for Design for Material Extrusion process, in line with EWF’s IAMQS system will serve as the proof of concept and will be extensively piloted with 105 participants to both validate and refine the aforementioned methodology and accompanying infrastructure. Finally, this methodology can go beyond the barriers of just training for Design in Additive Manufacturing and can be adapted and transferred to other professional profiles both in AM and other industries and sectors. This topic will be separately addressed under A5.2 “Transfer to other profiles in AM”, once both the novel methodology as well as the necessary infrastructure are validated and refined for the initial DfAM profile.

4.1. Ecosystem

ShakeAM provides a route to qualification as an AM designer, but also has a series of additional elements that comprise the ShakeAM ecosystem. The ecosystem is divided into three main components, which are seamlessly interconnected, namely: a) the Skills.Move platform, b) the AGORA platform and c) the Classroom, that host all the envisioned functionalities presented in detail below.

Skills.Move Platform - Skills.Move is the digital learning platform of EIT Manufacturing supporting Europe’s manufacturing industry to upskill and reskill its current and future workforce by providing individuals easy access to a personalised learning experience. Skills.Move is based on the most prevalent “Andragogy” theory about adult learning, where adults are considered self-directed learners and hence the educators of adult learners should be more focused on "facilitating" the learning, rather than "teaching". Skills.move is based on two components: Learning Nuggets and Learning Paths, interacting as shown in the diagram 4-1 below.

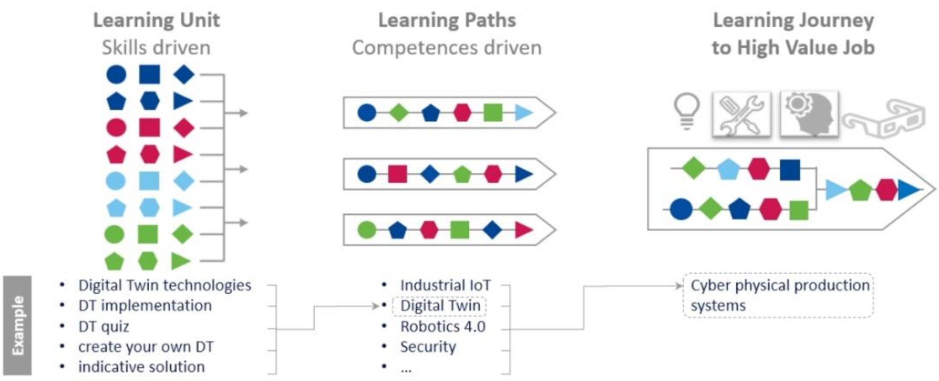

Figure 4-1 Components of Skills.Move platform

Nuggets (learning units) compile the main building blocks of the platform, which are self-contained learning elements composed by different didactic media like videos, text, images, animations, AR/VR sessions and learning assessments to achieve and to verify desired competencies or skills, with a maximum duration of 30 minutes (recommended 15 minutes) to engage learners. Each learning nugget can be consumed as standalone lesson, it should address at least one skill and have well defined learning outcomes that should be measurable.

There are different types of learning nuggets, namely: a) Info Nuggets: small elements that present learning content in a didactical way. They are used to get the competence level "knowledge", b) Set-up Nuggets: nuggets that describe a commissioning/setup procedure of a specific hardware or software, c) Task nuggets: learning elements that serve to acquire the competence components "knowledge" and "skill". These contain a didactical concept (e.g., leading text method, model of complete action) and a practical task or experiment and d) Question nuggets: learning elements that serve to challenge and thus reflect and strengthen knowledge. Question nuggets can be integrated in task nuggets for self-check of the learning success or be integrated in quizzes.

Learning paths are a compilation of three or more learning nuggets that address at least one competency and have well defined overarching learning outcomes. They include a) an introduction, with the description of the learning path that clearly states the topics illustrated, indicates what the learner will be able to do after its completion (learning outcomes) and defines the level of difficulty and pre-requisites, b) a core with interactive e-learning content and c) a final assessment that measures the achievement of the learning outcomes.

Agora Platform

AGORA is a new social network and open innovation platform for the pan-European manufacturing community created by EIT Manufacturing, an Innovation Community within the European Institute of Innovation & Technology (EIT).

AGORA aims to contribute to and stimulate manufacturing innovation and debate. It has three main purposes:

1. To act as an online meeting point for Europe's manufacturing industry.

2. To provide easy access to all facets of EIT Manufacturing activities, covering all aspects of the EIT Innovation triangle Education, Innovation and Business Creation.
3. To foster pan-European collaboration and debate about not only how but also what we manufacture.

AGORA's is organised into modules called Sphere's, where all networking, collaboration and information sharing takes place. AGORA offers different options for collaboration and co-creation directly inside the sphere. In each thematical Sphere the user is able to post in conversations, find other members, messages or documents. Moreover, users can directly join events and video conferences, and collaborate on files by viewing, sharing, creating as well as editing files directly on editable Word, PPT or Excel files.

Classroom

The classroom will facilitate face-to-face teaching, including both theoretical materials developed by the SHAKEAM project, as well as live demos and hands-on exercises for learners. Learners that are limited by geographical or other constraints or possess the necessary equipment themselves and prefer to join online, can still attend remotely, as the classroom will have all necessary infrastructure to facilitate remote learning and collaboration between learners and trainers.

4.1.1. Functional Areas – Structure of the Ecosystem

The ecosystem is designed such that students can:

- Access the course content for both synchronous and asynchronous learning paths for the course content
- Complete assessments that are required to obtain certification
- Discuss the course with other students and the trainers and provide feedback
- Find supplementary information to the syllabus material
- Find links to a wider network of DfAM relevant information and training sources

The ecosystem will exist across Skills.move and Agora, both of which are platforms hosted by EIT Manufacturing. Students and trainers will be able to access both platforms with a single login and move seamlessly between the two. The ecosystem and its functional areas will be hosted, interconnect and interact as shown in figure 4-2.

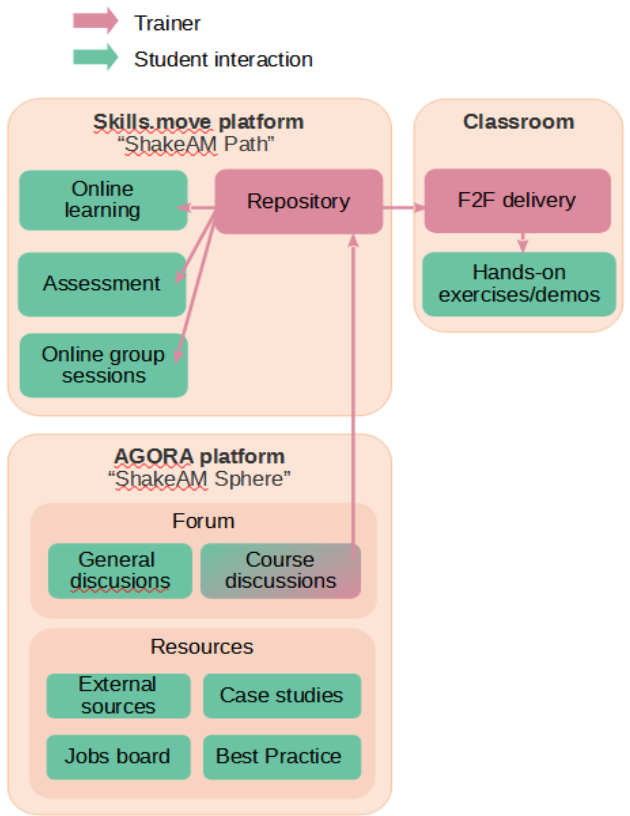

Figure 4-2 Functional areas of Ecosystem

4.1.2. Lifelong Learning Syllabus - Editorial Board

The ShakeAM editorial board will be composed by the project partners (consortium) that will, on a peer-to-peer review basis, approve all the content before it is made available to the public, and an external advisor. For the external advisor, the ShakeAM project will count with the support of the International Additive Manufacturing Qualification Council (IAMQC), managed by a European Management Organisation, which is responsible for setting the rules and procedures for the implementation of the AM Qualification System and its Quality Assurance Cycle. The IAMQC is composed by AM Authorised Nominated Bodies (ANBs), public and private research and/or industry representative organisations. The IAMQC is responsible for administrating the International AM Qualification System (IAMQS), including AM ANBs and AM Authorised Training Bodies (AM ATBs) that implement training courses. The IAMQC collaborates with the European Organisation Management Team and assesses the results from data analysis on AM skills needs (including entrepreneurship, digital and green skills) which are then validated by the International Additive Manufacturing Industrial Council (IAMIC) and decides if there is a need for revising Professional Profiles and/or Competence Units from AM guidelines or if there is a need to create new ones. If so, the IAMQC nominates an Education Working Group composed of experts in education and in AM, who will work towards updating or creating Professional Profiles/Competence Units with the help from the Industry Advisory Group, if needed.

4.2. Content Delivery

Content will be accessible through the Skills.move platform in the form of 'nuggets' that link together to form the learning path for the ShakeAM qualification. This online delivery method will provide an integrated learning and assessment experience. There will be a face-to-face delivery route as well, which can augment the learning experience, especially for SEND students. In this case, the Skills.move platform will still be the main learning and assessment route. The classroom can be used to have all students complete the online nuggets while in the classroom with the trainer. In addition, there can be a practical element - at the discretion of the trainer – which could include a physical 3D printer (with classroom-safe filament), design and build exercises and 3D printed artefacts. Train the trainers course will be implemented first. In this course the partners will be thought how to use the DfAM Ecosystem and Best Practises Database. This part comes under A3.4. EIT Manufacturing will be responsible for monitoring and guiding the partners. The training will also cover the most inclusive teaching techniques, how to be attentive to the needs of SEND pupils and underprivileged students, and how to use the appropriate teaching resources and tools. A group of participants will be able to use the DfAM platform and distribute material in the training pillar from within their individual institutions as a result of A3.4. Additionally, this will aid in spreading knowledge of the platform among other universities. The ecosystem framework will be improved using the attendees' feedback. Once A3.5 is done 2-4 participants of each partner organisation will be undertaking A4.5. This activity intends to equip instructors and trainers from SHAKEAM partner entities to provide the training materials for the project, which will be created under WP4. This means that in addition to the partners who will be actively involved in the pilots of those materials, those who were directly involved in their development in WP4 will also participate.

4.2.1. Teaching Environment and Inclusion

Most of the training is done online and a special E-Learning platform has been developed for this project. It contains two portals. Skills.Move is used for delivering teaching and Agora is used for getting feedback and conducting interactive sessions. In the skills move platform, the modules are delivered as nuggets and the students need to complete all of them. Meetings can be conducted using Agora to deliver group activities. Skills.Move platform need to indicate SEND students to the tutor so that special attention can be given to them. Also, it needs to make sure it has got necessary tools like subtitles, zooming the video, ability to change the time duration of the assessment for SEND students. There is a chance for an in-person session as well.

4.2.2. Teaching Environment and Health and Safety Issues

Trainers will have to ability to demonstrate and provide hands on experience with 3D printers, and as such, both them and the participating students must be aware of the health and safety guidelines that need to be followed to ensure no accidental harm is done to any of the participating parties. Live Training/Demonstration will adhere to the following HSE guidelines:

- Place the 3D printer in a place that has good ventilation.
- Follow the printer's manufacturer's recommended operating procedures, which include keeping the base plate and nozzle temperatures at the lowest possible levels to minimise potential emissions.
- Don't rely on the room's volume alone to lessen the impact. Despite being heavier than air, VOCs can be transported by natural convection and particulate matter.
- For FDM printers, use a 3D printer enclosure with a HEPA or activated carbon filter, and allow adequate exhaust for the emissions.

- Use products made by trustworthy companies. Blends that are inexpensive typically contain more aerosols.
- Keep an eye on the printing area's air quality frequently.
- Utilise PPE or additional protective measures appropriate for your use scenario.

4.3. Mapping of Existing Training Offers

The list below gives the topics that are partially covered in other EWF CUs in the field of Design for AM.

Competence Units – Simulation for Metals				
All Competence Units available on the International Additive Manufacturing Qualification System (IAMQS) Additive Manufacturing Observatory (ewf.be)				
CU			**Knowledge**	**Skills**
CU 61: Simulation Analysis **Subjects:** −Evaluation of Topology Optimization (TO) −Mechanical Analysis −Fatigue −Chemical −Thermal Analysis −Build Evaluation −Documentation −Case studies	**Level**	**Recommended Contact Hours**	Advanced knowledge and critical understanding of the theory, principles, and applicability of: −Topology Optimization −Stress and Strain Analysis −Phase transformations.	**Restricted**
CU 62: Simulation Execution	6 Advanced	21	Advanced knowledge and critical understanding of the theory, principles, and applicability of: −Validation and Calibration strategies −Application of the relevant Material properties, Boundary conditions, and mesh characteristics.	**Restricted**

Competence Units – Qualification International AM Designer for Polymers				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
CU 66: Designing Polymers Parts **Subjects:** −Think Additively −Design principles for AM −CAD files in AM −Simulation tools −Case study	6 Advanced	21	Advanced knowledge and critical understanding of: −AM design thinking −Design principles for AM −Simulation.	**Restricted**
CU 67: Post Processing for Polymers **Subjects:** −General considerations −Depowdering, cleaning, and support removal methods −Surface smoothing methods −Coating operations −Practical application	6 Advanced	3,5	Factual and broad knowledge of: −Post-processing methods (Depowdering, cleaning and support removal, surface smoothing, and coating operations).	**Restricted**
CU 68: Design for Material Extrusion **Subjects:** −Overview of Machines, Process Capabilities, and Limitations −Process-related Materials −Specific Design Considerations −Case study	6 Advanced	10,5	Advanced knowledge and critical understanding of: −State-of-the-art machines −Selection of the right machines for the purpose −Build size −Capabilities and limitations of process and influence on design −Design considerations required for MEX polymer part design	**Restricted**

Competence Units – Qualification International AM Designer for Polymers				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
			−Specific materials and their achievable properties and how to select them −Post-processing influences on design.	

Competence Units develop on Demo or Die (DEMO_OR_DIE DOCS_IO2_SV.pdf (demoordieproject.eu))				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
CU A: 3D Printing Material Extrusion (MEX) Overview **Subjects:** −MEX Process Overview −Overview on Polymer Materials, their properties, and applications	2 Basic	3,5	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.	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 **Subjects:** −Fundamentals of Computer-Aided-Design	2 Basic	3,5	Basic factual knowledge of: −3D CAD design and modelling process −3D solids and assemblies −File Preparation for 3D Printing.	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

Competence Units develop on Demo or Die (DEMO_OR_DIE DOCS_IO2_SV.pdf (demoordieproject.eu))				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
−Introduction to 3D CAD Software −Solid Modelling −Preparing for 3D Print – File Formats				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 **Subjects:** −Think Additively −Material Extrusion Overview −Design Principles/Specific Design Considerations −Slicing and Print Preparation	2 Basic	3,5	Basic factual knowledge of: −3D Design Thinking −Design Principles for MEX −Capabilities and limitations of process and influence on the design −Design considerations for MEX polymer's part −Slicing and Print Preparation.	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. Recognize 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 **Subjects:** −3D printing operational settings	2 Basic	3,5	Basic factual knowledge of: −3D Printing operational settings −Post-processing methods for polymers (Cleaning and support removal, surface smoothing, and coating operations)	Set up a 3D printer by following all the operational steps required. Recognize the required Health Safety and Environmental measures linked to

Competence Units develop on Demo or Die (DEMO_OR_DIE DOCS_IO2_SV.pdf (demoordieproject.eu))				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
−Post-processing for polymers −Trouble shooting			−3D printing problem-solving.	MEX 3D printing process. Recognize the need for post-processing operations on as-built parts according to the required part properties. Recognize the requirements that 3D parts need to comply with for each post process. Choose post-processing methods for a variety of part geometries, and 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: **Subjects:** −3D printing project "Do it yourself"	2 Basic	3,5	Basic factual knowledge of: - Developing a 3D printing project using MEX	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 the Slicing software. Set up a 3D printer by following all the

Competence Units develop on Demo or Die (DEMO_OR_DIE DOCS_IO2_SV.pdf (demoordieproject.eu))				
CU	**Level**	**Recommended Contact Hours**	**Knowledge**	**Skills**
				operational steps required. Recognize 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.

4.4. Links with existing AM projects

SAM "Sector Skills Alliance in Additive Manufacturing" focused to develop and execute the European sector skills strategy in AM. SAM identified the necessity for tools to support training delivery. The SHAKEAM project will address and meet this demand by creating an innovative ecosystem, a library of best practises, and a related training delivery approach. Additionally, the SAM project established a network of specialists from the AM industry and academia (AM Observatory), to whom SHAKEAM partners will reach out to request their opinions on the application of the project's training methodology. AMABLE will create a market for AM services targeted at SME-sized businesses that also offers a DfAM service. By supplying the educational component that AMABLE is lacking, SHAKEAM will enhance AMABLE. As a result, both platforms will work together to satisfy the consulting and training needs of present and future designers.

4.5. Content Structure/Learning Outcomes

This course covers the polymer material extrusion method. This is just one type of AM process, but one of the more widespread in use and one of the hardest to design for in the field of polymers. The consortium has good knowledge of AM process. So, the existing gap has been identified and the course module has been created for advanced-level students. Students will have the opportunity of learning advanced information that isn't easily accessible from other sources and can thus concentrate on "best practices" instead of fundamentals. There are some requirements to enrol for this course. The students need to be aware of the basics of the AM technology like various types of AM processes, when to use them and have basic competency in CAD software before enrolling for the course. The following content structure (overview) for the ShakeAM project Competence Unit (CU) covers the minimum requirements for education and training, which have been agreed upon by all project partners, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them. Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the CU level.

CU: Relevant Principles of MEX for Design	**RECOMMENDED CONTACT HOURS***	
SUBJECT TITLE	**THEORETICAL**	**PRACTICAL**
MEX Process Capabilities and Limitations (selecting the process)	2.5	-
Design for Process Chain • Data Pipeline • Design for Manufacturing (DfM) • Design for Post Processing (DfPP) • Design for Inspection (DfI) • Preparation for Manufacturing	7	3.5
Design for Sustainability	1	-
TOTAL	**14**	
EXPECTED WORKLOAD**	**28**	
ECTS***	**1**	
EQF****	**6**	

*RECOMMENDED CONTACT HOURS are the minimum recommended teaching hours for the standard routes.

**EXPECTED 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.

***European Credit Transfer and Accumulation System (ECTS)

****European Qualifications Framework (EQF)

The modules focused on this course are:

- Selecting the right process
- Design for process chain
- Design for sustainability

This new CU was created to bridge the gap in existing CU's that are been used in other EU projects

4.5.1. Selecting the right process

In this topic, the students will be learning about the basic parts of the MEX 3d printer and develop the ability to choose the right process. Knowing 3d printing hardware helps them to understand how the machine works and know about its specifications (build height, layer thickness, nozzle size etc.). This has a great impact on the part that gets printed. So, while designing a part these things need to be considered. This topic also focuses on when to choose AM process, its benefit over the conventional manufacturing process, what materials to use and the cost of the product produced by the MEX process. The knowledge of the student is tested by providing case studies or some exercises and asking them to answer certain questions based on their understanding.

4.5.2. Design for process chain

In this topic students will be learning about the AM data pipeline, design for manufacturing, design for post processing and design for inspection. They will be knowing about various instruments and methods to test the products. This topic also covers inspection of the part so students will also be gaining knowledge in quality control. Various exercises are given to students to master the topic mentioned above. Open-source materials will be shared for students who wish to learn more about this topic.

4.5.3. Design for sustainability

In this topic students will be learning how to reduce carbon footprints by using methods to reduce waste. This is the most important topic as it focuses on how to recycle the support structure or build that is failed. They will be having an insight into materials that can be recycled and reused and whether it reduces the cost of the product. Case studies can be provided to provide better knowledge on this topic.

4.5.4. Optimising the design/Redesign for AM

In this topic students will learn about how to optimise design for AM and how to redesign an existing part. This is the most important topic as it focuses on how to consolidate part, producing mating part and benefits of using topology optimization for weight reduction. While redesigning a part for AM lot of parameters needed to be considered and most of them will be covered in this module. They also be learning how to validate the design using FEA software.

5. Assessment Strategy

5.1. Evaluation mechanisms for assessment of the achieved learning outcomes, considering SEND Students

There are several assessment methods in Higher education, with the most commonly used being written exams. Examinations, like other assessments, are intentionally designed to determine who has met learning outcomes. However, they should not have the unintended effect of preventing diverse students from demonstrating their capabilities. Indeed, students with disabilities report selecting their units of study according to an assessment format that aligns with their strengths; many, as part of this, describe avoiding examinations (Waterfield, 2006; Morris, 2019). Since examinations are commonly harnessed for certification and accreditation purposes, it is necessary to understand what can be done to improve the inclusivity of examinations or assessments. Examinations are referred to a range of high-stakes timed assessment tasks, which can include written papers – both multiple choice and longer essay formats – and other types of tasks where students are expected to perform or produce individual work within a limited timeframe. (Bearman, 2017).

Examination-related disadvantages have been mitigated through adjustments' or 'accommodations' for students with disabilities in accordance with legislative requirements (e.g., Disability and discrimination, Common wealth of Australia (https://www.legislation.gov.au/Details/C2018C00125). Adjustments for students with disabilities frequently include changes to timing including extra time and breaks; changes in location such as a quieter, more physically accessible or individual room; and the provision of assistive measures such as a scribe or electronic devices However, adjustments do not always lead to equitable academic outcomes, nor address students' actual access requirements. Moreover, making individual ad-hoc adjustments is time-consuming and inefficient. A system that focuses on making reactive adjustments is likely to become overwhelmed as participation of students with disabilities in higher education continues to increase. (Tai, 2023; Anafin, 2007; Madriaga, 2010; Waterfield, 2006; Kilpatrick, 2017). With the shift to examinations online, as a result of Covid-19, many students found this more inclusive, especially being able to type answers rather than handwrite. For others, technologies such as access to computers had already been part of their examination landscape. An adjustment as simple as access to a computer made a significant difference for students with a mental health condition and learning disability.

Students reported the move to online examinations as improving inclusivity, primarily because of the increased flexibility offered around aspects including the examination's location, the assessment timeframe and the student's access to resources. While some students reported there were benefits to the routine of an in-person supervised examination, the majority described their online examination. Greater flexibility often means decreased standardisation, requiring a move away from a belief that fairness in assessment is based on equality (i.e. everyone performing the same task under the same standardised conditions) to one where it is based on equity (i.e. differentiating according to student needs to support capability and diversity) For greater flexibility in higher education assessment to become commonplace, this major philosophical shift needs to be embraced by all stakeholders, including those involved in accreditation and the future industries where graduates will work. (Tierney, 2013; Harris, L. R. et al 2020). Within ShakeAM project it is envisage the development of assessment methodology which fits SEND and non-SEND students' needs.

5.1.1. Considerations of assessment types

In activity A.4.2, when creating the modules assessment within the project, ShakeAM consortium will have in consideration the following:

a) The Learning Outcomes (LOs), with related assessment strategies and assessment criteria, should be defined for each Competence Unit (CU).
b) That after the CUs of the programme have been identified, the overall structure should be outlined and credits allocated to each component on the basis of its learning outcomes and associated workload, considering that 30 hours of workload will correspond to one point/credit.
c) That the credits must be awarded when appropriate assessment shows that the defined learning outcomes have been achieved at the relevant level of performance. If the trainee has not achieved the learning outcomes, no credits will be awarded. The number of credits awarded to a student who demonstrates the achievement of learning outcomes is the same as the number of credits allocated to the Competence Unit(s).

ShakeAM methodology will follow the general recommendations for ECTS credits attribution, according to the following calculation of credits assignment:

The Weight of the CU for the Qualification:

-Being focused on one job function, Functional CUs are determinants for the professional profile thus the assignment of 1 credit is made for an estimated workload of 21 hours while the assignment of 1 credit for a Transversal CU is made for an estimated workload of 28 hours.

The Expected Workload to Achieve the Learning Outcomes:

-The scope of the Transversal CUs is often broader, requiring a bigger workload to achieve the learning outcomes, therefore, 1 learning hour will correspond to 2 hours of workload for Transversal CUs and 1.5 hours for Functional CUs, respectively.

The rounding rule applied to the credit assignment is to round up to the closer quarter unit, as follows: [0.25]; [0.50]; [0.75]; [1.00].

TYPE OF CU	CALCULATION FORMULA	CONTACT HOURS	WORKLOAD	POINT/CREDIT
Transversal	Contact hours *2	35	7	0.25
Functional	Contact hours *1.5	21	31.5	1.5

d) That the assessment methods used to evaluate the student's achievement, must consider the actions and performance criteria that were established for the student to demonstrate that learning outcomes have been achieved. The assessment methods chosen for a Competence Unit must be consistent with the learning outcomes that have been defined for it and the learning activities that have been put in place.

5.2. Assessment types to be considered in ShakeAM project

Inclusive assessment tools for design for additive manufacturing students are essential to ensure that all students are evaluated fairly and equitably. Additive manufacturing is a rapidly growing field that requires students to have a range of technical skills, creativity, and critical thinking abilities. Based on a survey and analysis made by the ShakeAM consortium, we came up with the five best inclusive assessment tools for design for additive manufacturing students.

1. Self-assessment exercises.
2. Exam with multiple choice answers, with questions with similar structure of the self-assessment exercises.
3. 3D printing challenges: 3D printing challenges are inclusive assessment tools that provide students with opportunities to demonstrate their technical skills and creativity. 3D printing challenges can be designed to evaluate design skills, problem-solving abilities, and teamwork. Additionally, 3D printing challenges can be designed to incorporate diverse perspectives, such as designing for accessibility or sustainability.
4. Portfolio assessment: Portfolio assessment is an inclusive assessment tool that provides students with opportunities to showcase their work and skills over time. Portfolio assessment can be used to evaluate design skills, technical skills, and creativity, among others. Portfolio assessment is inclusive because it allows students to present their work in a variety of formats, such as 3D models, sketches, and written reflections.
5. Design thinking exercises: Design thinking exercises are inclusive assessment tools that provide students with opportunities to develop and apply their design thinking skills. Design thinking exercises can be designed to evaluate problem-solving abilities, creativity, and critical thinking skills. Additionally, design thinking exercises can be designed to incorporate diverse perspectives and design challenges that are relevant to a broad range of students.

5.3. ShakeAM Assessments

In term of the online assessments, it was identified five key design considerations for online assessments which much be followed, namely:

1. Assure academic integrity, for example ensures that the students don´t use someone else work (from the previous years).
2. Allow for provision of assessment quality feedback.
3. Support a positive learning experience for students.

4. Assure the confidentiality of student on formation.
5. Ensure all students have an equal chance to complete the assessment successfully.

After consortium analysis and discussion of the available information and studies concerning online assessments, it was decided that the exam format should be Multiple choice questions (with 1 to 4 answers possible correct answers with discount) and when applicable some exercises. It should be noted, that when require by the students the same exam can be made in person. Also, it is envisaged to create group project base learning, for the modules where it can be applied. This type of evaluation can be made both online and physically.

5.4. Assessment Feedback

The students should receive an appropriate level of general and/or individual feedback on all assessed work to promote learning and facilitate improvement. Feedback should be provided to the students within 20 working days of the submission date. The type of feedback the students will receive will depend on the type of assessment and will be defined by the course team. Feedback can include:

- Marks for the work provided in accordance with the qualitative descriptors detailed below
- Individual written feedback, outlining strengths and weaknesses of the assessed work; this may be provided on a feedback form, a written report, or via email
- Group written feedback, provided as reflective feedback on the assessed work
- Provision of exemplars, so that the students can reflect on how to improve their own work
- Individual oral feedback, particularly for small cohorts or individual presentations
- Group oral feedback, such as revision lectures or post-assessment workshops

5.5. Exceptional circumstances and alternative arrangements in assessments

The examiners have full discretion to modify the usual arrangements for examination and assessment to take account of a candidate's particular requirements (e.g., additional time for those with dyslexia, coloured examination papers, use of computers or a personal scribe (amanuensis) in examinations, if necessary, etc.). Any candidate wishing to seek approval for such an arrangement should contact Tutor in the first instance, normally at least two months in advance of the examination (unless exceptional medical circumstances prevent such prior notice) to ensure that sufficient time is available to make the appropriate modifications.

NOTE: usually to SEND students shall be given 25% additional time in formal examinations i.e., an extra 15 minutes per hour in addition to any other recommendations made by an appropriately qualified educational psychologist.

5.5.1. Students covered by special educational needs status.

Students with Special Educational Needs (Students - SEN) are considered to be students covered by the categories defined by the OECD, which are CTN. A and CTN. B, where:

a. <u>Transnational category A (CTN. A):</u> includes students with disabilities considered in medical terms as organic disorders, attributable to organic pathologies, for example, associated with sensory, motor or neurological deficiencies. Educational need is considered to arise primarily from problems attributable to these deficiencies.

b. Transnational category B (CTN. B): includes students with behavioural or emotional disorders or with specific learning difficulties. It is considered that the educational need arises primarily from problems in the interaction between the student and the educational context

Proof of the conditions for granting the Student-SEND status

1. The application of the Student-SEN statute is required at the competent service, at the beginning of the course (unless the condition only applies manifest later or result from occurring after the beginning of the course).
2. The application must be accompanied by supporting reports or opinions issued by specialists, namely doctors, psychologists, speech therapists or others suitable for each specific case, indicating whether the condition is permanent or temporary.
3. In the case of permanent SEN-Students, the application referred to in the previous number must be submitted only once.
4. In the case of temporary SEN-Students, the student must periodically provide proof of the condition.
5. The reports or opinions must be substantiated, namely explaining the type of condition and its severity, depending on the work to be carried out by the student during university attendance, namely in the following areas:
    a. Vision
    b. Hearing
    c. Motor capacity
    d. Chronic illness
    e. Psychological/Psychiatric
    f. Learning Disabilities
    g. other objectively limiting conditions with implications for the teaching-learning context.

6. Whenever necessary, additional documents may be requested in order to complete the individual process of each student.

7. The recognition of the Temporary Student-SEN Statute is annual.

5.6. Pass criteria for an overall award

In order to achieve their award, the students are required to achieve:

- An overall average mark of ≥60%.
- An average mark of ≥50% across the taught assessment.
- All assessments need to be completed and the minimum mark attained: no more than one failure to complete an assessment will be permitted throughout the course of the studies.

In the case of the assessment being made by multiple choice questions, The following should be considered:

- Average time allocated to answer each question: 1min 20 sec (as an average value) for EWF Advanced level (EQF level 6)
- Minimum number of questions per examination on each Competence Unit:
    - 1 Question per subject (at least)
    - 1 Question per each recommended training hour
    - Each question has four answers, and the correct answers can be 1 to 4.

- The final rate for approval to the CU shall be at least 60% of the average scoring on the examination + at least 60% attendance to the training

The required credits for the award will be outlined in the A4.1

6. Conclusion

The ShakeAM's digital ecosystem serves as an impartial "one-stop shop" for AM design in Europe. The ecosystem consists of a number of interconnected functional areas housed on a platform by EIT Manufacturing and it promotes best practices. An advanced-level Design course was developed for the polymer Material Extrusion process. The targeted audience were HE students and the people who are already pursuing their career as a designer. The trainers are given training to teach the students. This course was made in a way that contributes to inclusion by accommodating SEND students. To fill the gaps in the current CUs that have been utilised in previous EU initiatives, new CUs are being developed. The layout and course delivery method has been discussed by the partners. The editorial board has been set up and managed by the partners of the project to peer review the content before its available to public. This board make use of IAMQS to manage the operation. The content is delivered through Skills.move platform in the form of nuggets. Agora is another kind of platform from EIT Manufacturing which is used to collect feedback, conduct meetings and it also act as social network platform for education. Most of the training take place online through these two platforms. The assessment will be taking place in the form of multiple-choice questions and some exercise can be added which will be discussed in the WP4. Twenty five percent extra time will be devoted to the SEND students in usual formal examination and same can be considered here. Feedback is given to the students within 20 working days of the submission date. To encourage the adoption of the technology in numerous EU industrial sectors, the project will increase the visibility of pertinent AM professional profiles.

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