Training Manual for Teachers and Trainers

Project Nr: *2021-1-PT01-KA220-VET-000034876*

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Content

1. Introduction

The purpose of this manual is to provide an in-depth understanding of how the developed materials in AREOLA project could be used in training program for additive manufacturing in the Aerospace Powder Bed Fusion - Laser Beam (PBF-LB) Operators qualification. The target group for this training manual is primarily vocational education and training centres' trainers and educators looking to deliver a more comprehensive and innovative training solution. By utilizing online theoretical training materials and augmented reality and virtual reality digital tools for practical training, learners will have access to the newest and most advanced manufacturing processes that would otherwise be unavailable due to prohibitive costs, safety risks, and logistical challenges.

The content of this manual includes detailed information on the International Additive Manufacturing Qualification System (IAMQS), the importance of understanding different types of learners, and the psychology of learning, and coaching activities. Additionally, lesson planning and evaluation of the learning process are discussed in-depth to ensure that learners achieve the expected learning outcomes.

We hope this training manual will provide you with the necessary information to achieve success in additive manufacturing training for Aerospace Powder Bed Fusion - Laser Beam (PBF-LB) Operators qualification.

2. Project information

2.1 About Areola project

AREOLA Erasmus Plus [1]. Project arises from the need of having a more resilient solution in terms of training, providing solutions to boost the educational transition to the digital era.

With AREOLA, the additive manufacturing training for Aerospace **Powder Bed Fusion – Laser Beam** (PBF – LB) Operators qualification will be able to be delivered in a blended learning environment using online theoretical training materials and innovative Augmented Reality and Virtual Reality digital tools. With these new solutions, AM Vocational Education and Training centres will be able to deliver a more comprehensive training aligned with the quality standards, assured through the close relationship with AM Networks and Aerospace industry.

AREOLA will support the recovery of the Aerospace, ensuring training excellence in the field, with support of innovative virtual training environments.

[1]https://areola-am.eu/

2.2 The International Metal AM Operator for PBF within the IAMQS

The International Additive Manufacturing Qualification System (IAMQS)

The fast evolution of technology and the quick changes in the production process, especially in additive manufacturing, demands a harmonized qualification system. The challenge of European Education and

Training providers is to swiftly reply to Additive Manufacturing (AM) Industry's skills needs and mismatches, to cope with the rapid changes of this key enabling technology.

The International Additive Manufacturing Qualification System (IAMQS), managed by the European Federation for Joining, Welding and Cutting (EWF), was created in 2018 to ensure that companies and professionals are equipped with the right set of skills to implement Additive Manufacturing at the industrial level. IAMQS assures harmonized development of knowledge and skills, for any holder of a diploma, in any region of the world, and comprises Education, Examination and Qualification Guidelines for different professional levels.

The quality assurance system, underpinning the IAMQS, guarantees its relevance, competitiveness and harmonization. As a result, trainees have access to the same training content and assessment procedures, regardless of the country in which they are taking their courses. The IAMQS works closely with the stakeholders from AM ecosystem. This way, it can ensure that the developed qualifications fit the needs and requirements of industry, but also, is aligned with Vocational Education and Training (VET) providers and Higher Education institutions requirements and individual's needs.

The Qualification System is composed by different Qualifications structured in competence units (short learning units enabling several accumulation and combination options), used to describe the expected knowledge and skills acquired by professionals after the successful completion of the training courses.

Nowadays, the system offers twelve Qualifications in Additive Manufacturing that have already been implemented in seven countries, namely: France, Germany, Italy, Portugal, Spain, Turkey and United Kingdom including Republic of Ireland). The IAMQS covers different AM professional profiles, in particular Operator (Independent level, aligned with EQF 4), Supervisor (Independent level – aligned with EQF4) Designer (Advanced level, aligned with EQF 6), Process Engineer (Advanced level, aligned with EQF 6), and Coordinator ((Advanced level, aligned with EQF 6).

Figure 1-International Metal AM Qualifications (IAMQS)

Each qualification is composed of different Competence Units (CUs) according to the specific AM professional profile. Moreover, the system encompasses transversal independent CUs that can be included in the tailored training, namely: the CU for Certification, qualification, and standardization in AM; Business in AM and Sustainability for AM.

Progression within a career plan

Within the IAMQS upskilling pathways are foreseen among different AM specialization areas (e.g., Operators and Process Engineers), enabling professionals to progress with their knowledge, and their career, by obtaining new skills and knowledge inside the Qualifications System. The progression of levels is made from the lowest to the highest level in building blocks. The highest levels start the training courses along with the lowest levels ensuring the development of solid fundamental knowledge and skills of concepts and principles. Upon successful completion of the lowest levels, learners start more complex levels.

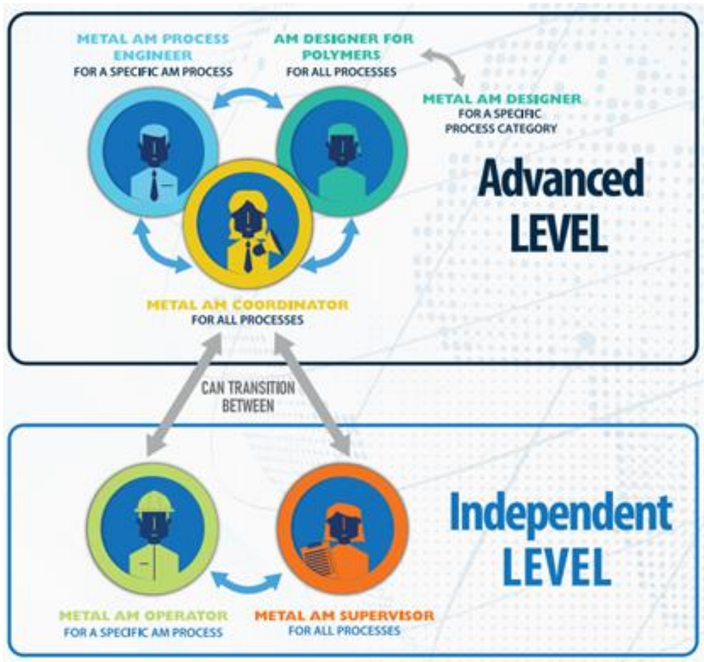

Figure 2 - Progression within IAMQS

Examples of this progress are provided in figure 2. In Independent level, with additional completion of specific CUs, a Metal AM Operator can directly access to Metal AM Supervisor. The same progression is possible in Advanced Level. The qualifications with additional completion of specific CUs can directly access to others qualification in the same level: Metal AM Coordinator, AM Designer for Polymers, Metal AM Process Engineer.

The progression to other qualification level is also possible, but, if other access conditions are also met, for example graduation in specific areas.

For this, the IAMQS system have two types of Competence Units, the Functional and the Cross Cutting.

The Functional CU means that the learning outcomes are directly linked to at least one job function. In this pathway, the knowledge and skills achieved will be mobilized in specific job functions and related activities.

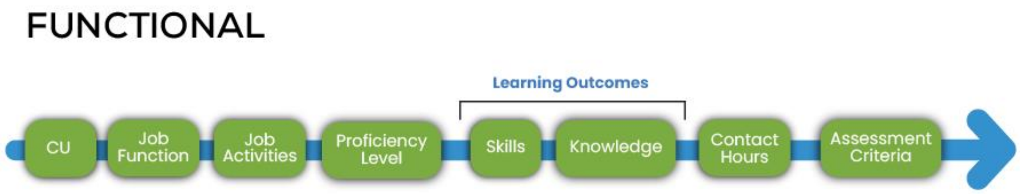

Figure 3 - IAMQS Fuctional CU

The Cross Cutting CU means that the specific CU are not linked to a job function, the knowledge and skills achieved can be part of several job functions and cross several activities.

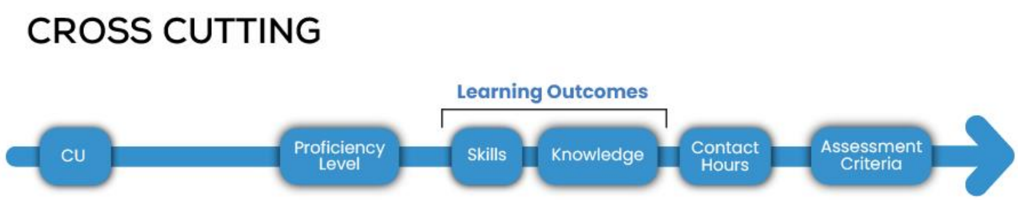

Figure 4 - IAMQS Cross Cutting CU

The add value of this modular and cumulative system is target in the AM ATBs, VET providers and HE institutions - learners attending the qualifications - and industry, itself:

- One single Competence Unit can be common to different Qualifications -cumulative system
- One single Competence Unit can be common to different Qualifications -cumulative system
- Students can easily progress within the System by accessing other Qualifications or accessing higher and lower levels Qualifications.
- Companies benefit from "fit-to-purpose" Qualifications/training courses

EWF Qualification Framework (i.e. Proficiency Levels) ensures transparency to all IAMQS Qualifications, allowing recognition and linkage to National and European Qualification Frameworks, which facilitates their integration at National level.

The International Metal AM Operator Powder Bed Fusion – Laser Beam (I MAM O PBF-LB)

The Powder Bed Fusion – Laser Beam Operator is the professional with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using PBF-LB Process.

The main tasks are related to operating powder bed-based Laser beam machines for Additive Manufacturing, including fitting and setting up, maintenance and repair. This professional, at the end of the training, will be able to remove parts and prepare them for post-processing steps and to develop solutions on basic and specific problems related with powder-bed-based machines and processes for Additive Manufacturing.

The International Operator PBF -LB Qualification Course is addressed to professionals having no experience, knowledge, skills and competences in the field of PBF-LB Additive Manufacturing or candidates having experience, but willing to upgrade their knowledge. Apart from an International recognised qualification which increases employability in the labour market, though mobility and skills transparency, this qualification will also give the opportunity to have an up-to-date knowledge, skills and competences regarding the PBF-LB Additive Manufacturing process and gaining a formal recognition of a qualification to act in the field of Metal Additive Manufacturing using PBF-LB process.

To have access to this qualification it is necessary to have a National compulsory school diploma.

To fulfil the International Operator Powder Bed Fusion – Laser Beam qualification, the following route is necessary. There are specific competence units that are mandatory to be completely with success.

Also, there two optional competence units that can be accessed, in addition to the required course content.

Required Course Content

#CU	Title	Recommended Hours
00	Additive Manufacturing Processes Overview	3,5
15	PBF-LB Process	14
16	Quality Assurance (QA) in PBF-LB	7
17	Health, Safety and Environment (HSE) in PBF-LB	3,5
18	Hardware, software and build file set-up for PBF-LB	14
19	Monitoring and managing the manufacturing of PBF-LB parts	3,5
20	Post processing of PBF-LB Systems	7
21	Maintenance of PBF-LB Systems	7
	TOTAL:	**60h**

Optional Course Content

#CU	Title	Recommended Hours
48	Powder Handling	7
49	Laser Beam Characterisation	7

The frequency of the competence units can be done to achieve the qualification, with the success in all CUs, but also, the frequency of these CU can be done independently and individually.

2.3 CU21 and usage of Areola theoretical material

The Competence Unit (CU) 21 Maintenance of PBF-LB systems is part of the CU required for the course content of International Operator Powder Bed Fusion – Laser Beam, Independent Level/EQF 4.

The CU 21 is a functional competence unit, meaning that it is directly linked to at least one job function, which in this case is "Maintain and repair the PBF-LB system". In this pathway, the knowledge and skills achieved will be mobilized in specific job functions and related activities, namely:

Implementing equipment manufacturer's maintenance routines

Cleaning and replacing, materials components (e.g., powder bed, cleaning agent, filters, cover glass)

Reporting problems to the Engineer

Following applicable HSE procedures

The achievements in this CU will allow students and trainees to upskilling pathways, either within the same field of activity or among different specialization areas.

The theoretical materials developed in AREOLA project covers all the subjects foreseen in CU21:

CU 21: Maintenance of PBF-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
General maintenance aspects	2
Optical elements	0,5
Parts maintenance	1,5
Auxiliary elements maintenance	1
Application driven material change	1
HSE Procedures	1
Total	**7**
WORKLOAD	**14**

<table>
<tr><th>CU</th><th>EQF/ EWF LEVEL</th><th>JOB FUNCTIONS</th><th>JOB REQUIRED ACTIVITIES</th><th>CONTACT HOURS</th><th>WORK-LOAD</th></tr>
<tr><td rowspan="4">Maintenance of PBF-LB systems</td><td rowspan="4">4 INDEPENDENT</td><td rowspan="4">Maintain and repair the PBF-LB system</td><td>Implementing equipment manufacturer's maintenance routines</td><td rowspan="4">7</td><td rowspan="4">14</td></tr>
<tr><td>Cleaning and replacing materials components (e.g. powder bed, cleaning agent, filters, cover glass)</td></tr>
<tr><td>Reporting problems to the Engineer</td></tr>
<tr><td>Following applicable HSE procedures</td></tr>
</table>

In terms of Learning Outcomes, the detailed knowledge and skills identified for this competence unit are below:

LEARNING OUTCOMES – CU 21: Maintenance of PBF-LB systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with PBF-LB systems
SKILLS	Change protective lens and clean the nozzle Assess the need to perform maintenance operations inPBF-LB system Perform maintenance operations in a PBF-LB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the optic system Verify if the optical system is working correctly Monitoring and calibration status Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

The frequency of the CU will lead to an examination, and to a record of achievement, if the examination is performed with success. The examination is also harmonized, meaning that all students and trainees will perform the same exam, a harmonised exam matrix, in the same conditions, independently of the country or region.

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IAMQS AM Catalogue

https://www.ewf.be/iamqs/files/am-cataloguev2.aspx?v=%3d%3dHAAAAB%2bLCAAAAAAABABLLk6zNVRLzC2wLk9NgrJSbVNNEx0DygDOk5ECHAAAAA%3d%3d

AREOLA Project

https://areola-am.eu/

3. Psychology of learning (basics of learning)

Hoffman and Engelkamp (2013) emphasize that learning is a knowledge, skills, and behavior change resulting from individual experience. Several factors play an essential role in personal experience. Three key pedagogical concepts are outlined below in this regard.

Motivation

Hasselhorn and Gold (2022) define motivation as "[...] a person's willingness to engage intensively and persistently with an object." (English translation of German citation, Hasselhorn & Gold, 2022, p.101). A rough distinction is made between readiness triggered from within by one's interest in a particular subject, i.e., intrinsic motivation, and the externally controlled drive, extrinsic motivation (Rheinberg & Vollmeyer, 2019). Activities like learning are performed without a controlling instrument when intrinsic motivation is present, whereas extrinsic motivation ceases when the external drive is removed (Brandstätter et al., 2018). Accordingly, we consider intrinsic motivation in pedagogy's context in the following.

Here, the leitmotif of central importance distinguishes achievement, connection, and power motives (Brandstätter et al., 2018). In the achievement motive, there is an engagement with an individually set standard of quality that needs to be achieved - when learners engage in solving challenging tasks and experience themselves as competent in doing so. In this process, the learner's hope for success (success motive) and fear of failure (failure motive) come to the fore. Success-motivated and failure-fearful individuals can be distinguished in their causal attributions, i.e., to whom or what they attribute the cause of their success or failure (e.g., Hasselhorn & Gold, 2022; Adenstedt, 2021). Success-motivated individuals typically attribute their success to their abilities and applied effort, whereas failures are attributed to a lack of action or external circumstances. In contrast, failure-fearful individuals attribute failures to a lack of knowledge but success, not to their ability (Brandstätter et al., 2018). Attributions can have a learning-promoting function if they encourage learners who justify their failure by lack of effort to make further learning efforts. However, they can also inhibit learning behaviour when failure-fearful learners are confronted too frequently with their self-assumed lack of ability (Hasselhorn & Gold, 2022).

The connection motive, in contrast to being driven by one's performance, refers to the existence of other people. Learners with a strong connection motive strive to connect and cooperate in the learning process and perform well. They do not want to be challenged in competition but rather enjoy a sense of communal well-being (Brandstätter et al., 2018).

The third motive, the power motive, builds on competition as an incentive. This is based on feeling an incentive when one's performance is superior to others or influences fellow humans (Brandstätter et al., 2018). In the educational setting, trainers should try to tickle learners' intrinsic incentives rather than build on extrinsic motivation due to its lack of lifespan. Learners differ in their leitmotifs, and reference should be made in the teaching situation. For the achievement motive, it seems beneficial to focus on personal control, for example, by providing feedback to assess effort (Schnotz, 2011). Learners should also be encouraged to set realistic goals and practice appropriate self-assessment (Borcher, 2007) to ensure success. Where group works and collaborations prove positive for connection-motivated learners, learners with a strong power motive perform well when compared to others, and they emerge as the strongest (Brandstätter et al., 2018).

Ways of learning

In addition to motivation, different ways of learning must also be given central importance. Learning in an increasingly complex world is unlimited in time and space (Harring, Witte & Burger, 2018). The learning process does not exclusively occur in organized and institutionalized settings such as schools or other further education institutions (formal learning). However, learning can be an integral, unconscious part of everyday events (informal learning). In the latter way of learning, we include activities such as reading a book or trying to rebuild the shelf we just ordered with the manual only that we will not receive a certificate or need to take a final assessment like it is the case in formal learning (Kerres, Hölterhof, & Rehm, 2017). Informal learning cannot be directly controlled, but framework factors can be established that enable and reinforce learning experiences (Brodowski et al., 2009). Learning can no longer be understood as a classic model in this context. Instead, the learner is to be understood as an individual who completes his learning experiences in interaction with himself and the world (Kerres et al., 2017).

Which factors can be established in a formal teaching scenario to promote informal learning methods?

A basic approach is the possibility of self-study through specialized literature. Heyder (2015) emphasizes the importance of access to textbooks, journals, and digital and electronic (learning) media for self-selected learning activities to enable the possibility of self-study by providing information.

Another central point is "learning by doing". This involves trying and applying one's ideas (Decius, Schaper & Seifert, 2019). However, the path of learning by doing should not be independent of reflecting on what worked and what did not. Therefore, the teachers' or trainers´ task is to create space and incentives for reflection and evaluation (Becker, 2016).

A final point is model learning, where different cultural approaches and ways of thinking meet and enrich each other (Decius et al., 2019). Model learning is ensured when learners observe and integrate other behaviours into their behaviour. According to Heyder (2015), promoting the exchange of experiences, for example, with the help of information events, mentoring programs, expert forums, and learning groups, is particularly beneficial.

Types of learners

Until today, learning types are central to some discussions around pedagogical psychology, and teachers orient their teaching toward these learning types. Learners are divided into groups that differ, for example, in terms of their learning preferences or the sensory channels with which information is best absorbed (Burger & Scholz, 2014; Grotehusmann, 2008).

Some researchers find this theory controversial. Instead, they refer to action-oriented teaching and learning. In contrast to purely cognitive frontal teaching, the action-oriented approach includes cognitive, emotional, and practical aspects (Looß, 2001).

An idea of Looß (2001) describes that teaching must be oriented as follows instead of just distinguishing between four types of learners: Learners need space for knowledge construction in a self-study time where they learn independently. Each person's previous experience and knowledge must be considered in all fields. Otherwise, the learners may be over or under-challenged. Furthermore, the social exchange must be given to learning from different beliefs, thoughts, and opinions. As was shown in the motivation part of this summary, some students are mainly motivated when others are around, which is why this needs to be included in every teaching scenario (Brandstätter et al., 2018). Lastly, teaching should move away from classic rote learning via more complex tasks such as problem-solving (Looß, 2001).

In this reorientation, or the steering away from differentiating between learner groups, the learner is at the center. Different methods can be applied, like self-study time, social exchanges, and actual tasks instead of listening and receiving information. Rather than learning types or styles, these learning methods support picking up the different leitmotifs and open up different ways of learning.

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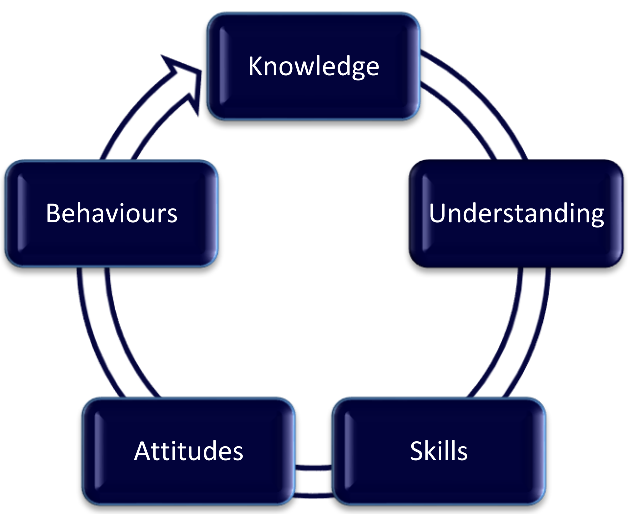
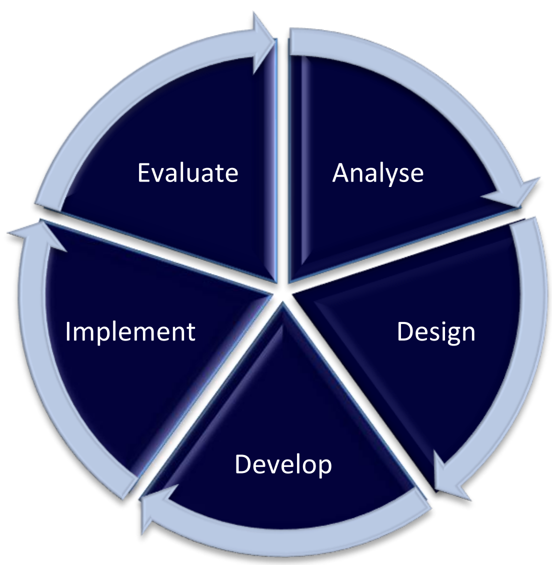
4. Coaching activities

The methods will need to facilitate learners' access to some of the world's newest and most advanced manufacturing processes, which would otherwise be unavailable to high volumes of learners due to the prohibitive costs, safety risks, and logistical challenges presented by a high value advanced manufacturing laboratory environment. The purpose will be delivering vocational learning more quickly, more efficiently and more effectively. It will increase the adoption of new technologies, standards and ways of working and work towards a decline in safety issues related to additive manufacturing required skills and behaviours.

To meet this aim, we recommend the following approach and models.





Using this approach to developing training and course design is based upon the understanding of the tasks, structure and competencies required by the sector for the future. The project will benefit from using the KUSAB (Knowledge, Understanding, Skills, Attitude, Behaviours) and ADDIE (Analyse, Design, Develop, Implement, Evaluate) design models illustrated above.

Using this holistic approach to training and course design follow proven methodologies, to ensure that the learning intervention focuses on true skills gaps of the individual, and that the coaches are fully compliant to deliver effective training to the needs of the individual.

Assessing an individual's knowledge using the ADDIE principal **Analyse** and **Evaluate** at the end will effectively demonstrate that knowledge has been obtained. An example capability profile is shown below.

Coaches using this model ensures full support throughout all the stages of the upskilling, enhancing their capability to deliver effective, engaging and memorable training to the learners.

5. Lesson planning

Preliminary considerations and key questions

Planning lessons is a complex process, so all considerations should be documented in a structured way. A lesson plan not only serves as an aid to the creator in carrying out the lesson but can also be used to make the objectives transparent to the learners or to make the planning accessible to third parties.

The planning of a learning unit is divided into three phases: The preliminary considerations, the implementation, and the reflection. These phases are directly interconnected and influence each other, so that planning does not only take place in the run-up to the actual lesson but is also adapted to the situation during the lesson and reflected upon and adapted afterwards to improve subsequent lessons.

Most of the planning, however, takes place in advance. Here, one should be guided by basic key questions:

- What learning content and objectives do I want to teach?
  (Where can I find predefined content and how can I formulate goals in such a way that they are verifiable in the retrospect)
- Which learning group am I dealing with and what is their prior knowledge?
  (Do the trainees have previous experience in the relevant field or are they already working in this industry, ...?)
- What is my own previous experience and where do I have possible gaps in my knowledge?
  (What further questions might arise during the class and do I have enough background knowledge?)
- What other conditions do I find in the learning environment?

(Does the teaching take place in presence or distance? Which visual objects can be used?)

Only when these questions have been conclusively clarified the detailed planning should begin. For this purpose, the learning objectives should be formulated first. These should always be oriented towards the learners and be verifiable by means of a final test. Reflection on the effectiveness of the learning unit is only possible if these have been formulated in this way.

Once the objectives have been defined, the lesson can be planned in detail. For this purpose, a tabular overview is provided. Here, time guidelines, teaching phases, learning objectives, methods and material can be presented in an easily understandable way briefly. An example of such a tabular overview can be found in the next subchapter.

As mentioned above, planning should be flexible enough to allow for minor adjustments during implementation. Furthermore, the teacher should take notes in order to include them later in the evaluation phase and thus continuously improve the lessons. A final test can also be a useful tool for the teacher to check the success of the lesson.

Structural tools (tables)

The following tables should be used to plan complete instructional units with a scope of several individual lessons (macro sequence). The individual learning units should be structured more precisely (progression plan). For this purpose, an organizational proposal in tabular form can be found below.

Table 1: Lesson plan template for macro sequence

Project: AREOLA	areola
Lesson plan template	Project Nr: 2021-1-PT01-KA220-VET-000034876 Co-funded by the Erasmus+ Programme of the European Union
Subject:	
Venue:	

Date	Time schedule / Duration	Content / Subjects	Learning outcome / objective	Resources (material and methods)	Lecturer / responsible
28.07.2023	*2'*	*Basics*		Classroom / Teams	

Table 2: Template for planning individual learning units (progression plan)

Project: AREOLA – Planning of individual learning units	areola Co-funded by the Erasmus+ Programme of the European Union Project Nr: 2021-1-PT01-KA220-VET-000034876
Trainer / Teacher:	
Date:	
Time:	
Module:	
Topic / subject:	
Venue:	
Learning objectives / outcomes:	

Stage:	Starting Time/ Duration (min)	Topic/ Content/ Subject/ Activity	Teaching and learning methods/ social type	Media/ Tools/ Resources	Learning outcome	Student evaluation
Introduction: …..						
Body/ Development: …..	*10´*	*Michael explains basics with the help of the materials*	*Teacher-student discussion; Method: expert learning: social type: group work*	*PPT*	*LO 1*	*e.g. final assessment*
Saving results/ Summary: …..						

6. Evaluation of learning process

The success of a learning process can be evaluated from several perspectives:

– The primary objective of any training program is <u>for the student to achieve the expected learning outcomes</u>.

- Efficiency in achieving the expected learning outcomes can be measured by assessing the appropriateness of the content, avoiding unnecessary repetition, and considering the time required for the student to complete the program.
- Interest and engagement of the student can be evaluated by considering the combination of content and teaching methodology, that promotes participation and generates satisfaction with both the content and the learning experience.
- The trainer's point of view is critical in identifying strengths and areas for improvement in the training course.

Therefore, to accurately evaluate the success of a training program, all these perspectives must be taken into account. They provide essential tools for assessing the quality of the content, the effectiveness of the teaching methodologies, and the achievement of the expected learning outcomes by the student.

Evaluation of an individual´s achievement of expected learning outcomes

In general, assessing the level to which a student has achieved the expected learning outcomes usually involves some form of testing, whether it be an oral or written exam, or the completion of some kind of practical assessment/case study. These assessments serve to demonstrate that the student has acquired the expected knowledge after completing the training, and act as evidence to third parties that this knowledge has been acquired and recognized. In the context of AREOLA's training courses, students will be able to demonstrate the acquisition of expected learning outcomes through two specific tools:

- For assessing the acquisition of theoretical knowledge, written tests will be conducted, requiring students to complete a multiple-choice questionnaire.
- For assessing the acquisition of practical knowledge, case studies will be conducted, taking various forms such as quizzes, written exercises, practical exercises using equipment, etc.

Aspects relevant to the preparation of these types of assessment tools include:

- Questions and case studies should always be directly related to the content covered in the section of the training course that is being evaluated. This means that questions should be related to information contained in the teaching materials or in the explanations and additional materials provided by the trainer.
- Regarding the design of multiple-choice questions, and within the context of the training activities carried out in the AREOLA project:
    - Questions should be brief and clear, easy to read and interpret, and requiring little time to select the answer.
    - The number of possible answers should be limited, but with a minimum of 4 options.
    - The assessment should prioritize the acquisition of concepts over the knowledge of highly specific data.
- Regarding case studies, there is some flexibility in their configuration, and their format can be variable. However, some general guidelines can be given for their design:

- The evaluation of the acquisition of knowledge with practical application should be prioritized over the evaluation of more theoretical content, which is more likely to be included in the evaluation methodology described above.
- The duration of the case studies should be limited, aiming to restrict it to less than one hour.
- Students should be presented with the cases clearly and concisely, identifying the basic aspects that make them up, and making clear the actions to be taken by the student.

Evaluation of an individual´s perception on training efficiency and engagement

The students will also have the opportunity to evaluate their level of satisfaction with the learning process, assessing aspects such as the following:

- The methodology used to develop the training action.
- The materials provided to the students.
- The ability of the trainers to transmit the intended learning outcomes, their preparation, and their interaction with the students.
- The use and management of time during the training action.
- The overall evaluation of the training action.
- The perception of its usefulness for their future employment.
- Aspects that have been more appealing and those that should be improved.
- Would you recommend the course?

The basic and objective instrument for the evaluation of the training action by the student would be the completion of a specific questionnaire. Ideally, it would be completed as a final stage of the training action, just after the completion of all the training activities.

Trainers should also have the opportunity to evaluate the training action, based on the development of a survey with the ability to ask questions similar to those mentioned above, but modified and adapted to the opposite perspective.

Integration of evaluation process results

Beyond their value as records, the results of the evaluation process for each training activity should be integrated into a general framework of continuous review of the training contents, teaching methodologies, and learning outcomes established for the training, in order to identify specific improvements for both the different training modules/competence units, and the programs in which they are embedded.

7. AREOLA Theoretical teaching material

Within Project Result 2 (PR2 - Development of materials to deliver PBF-LB Operator Theoretical Training) of AREOLA project, the consortium developed theoretical teaching material for the International Metal Additive Manufacturing Operator (IMAM-O) profile, which was then tested through piloting activities in each partners country. The consortium chose to develop material for the maintenance of PBF-LB systems and on powder handling. After the piloting process, the achieved results, especially the feedback of participants and trainers was analysed, and the theoretical material was revised according to the main feedback given. This chapter links the developed material free for a download as well as some hints and best practices how to use AREOLA teaching material in own courses focusing on Aerospace. Further information on the usage of AR/VR tools and on the practical material of AREOLA project will be given in a separate report focussing on Project Result 3 (PR3 - Development of VR/AR tools to deliver PBF-LB Operator Practical Training) results.

Theoretical teaching material for download

All results developed within AREOLA project are available on the website of the project (https://areola-am.eu/) in English, Portuguese, Spanish and German language. Please use the link (https://areola-am.eu/results.html) or the QR code below for the access to the material.

SCAN ME

Figure 5: Access to results of AREOLA project

Recommendations and best practices how to use the AREOLA theoretical training material

Please consider the following recommendations, information and best practices when using the AREOLA material for preparing your own teaching courses:

Resources and Tools	Recommendation / Information
Slides and presentation	- The AREOLA slides have been revised based on feedback from the pilot activities, but you may adapt the material for your own lectures. Recommended customisation by: o Preparing your own teaching notes based on the AREOLA slides and presentations provided o Reducing the amount of text per slide if required o Reduce the usage of abbreviations o Consider the background and level of participants and modify or simplify the content if necessary - Best practices from Areola piloting activities: o Additional inductory content on Additive Manufacturing was required for newcomers in 3D printing to be able to follow the CU21 and CU48 courses o The course content, delivery and assessment methods should be clearly explained to participants o Repeat the most important aspects of the content briefly after each session o Videos and practical examples support the theoretical presentation o Interactive tasks such as quizzes or games during or at the end of each session have been very positively evaluated to review the content and engage participants o During a virtual presentation, a real PBF manufactured part could be shown and explained to the participants via camera o It is recommended to have shorter sessions and more breaks when conducting online courses
Teaching notes	- Teaching notes are prepared for teachers and trainers to guide them with the content provided in the slides. - In case teachers or trainers would like to use them as slide notes, their own teaching notes should be prepared on the basis of the Areola material, which could be checked for information. - Based on the proficiency level and needs of the target audience, the slide notes could be tailored.
Case studies	- All case studies were transferred to Power Point / PPTS file formats according to the preferred mode of the instructors of the

	pilot courses (which were considered better for virtual classes). The case studies are structured as a quiz section with questions and answers on different slides. - The case study "Failed aeroengine" can be adapted to suit the level of audience and background information. - The case study "H&S investigations" can be adapted to suit the level of audience and background information. - The case study "PBF-LB Recirculating Filter System (RFS)" should be done after the full presentation of CU21 and not inbetween, since the information required to solve the case study is given in separate sections of the presentation. - Different interactions with the case study are recommended to stimulate students' autonomy and to encourage interactivity: - Provide the case studies as group work - Integrate the case studies into the lecture - Consider the case studies as homework
Lesson plan	- It is recommended to consider the recommended contact hours from the guideline and to adapt the course duration based on the level of the group.
Assessment questions	- The assessment questions for the slides were developed and tested in the pilot courses. - The assessment questions are suitable for testing the level of knowledge. - The questions are not be published. - If the assessment questions are to be integrated into the pool of the IAMQS system, they must be adapted to the relevant specifications.

<u>Recommendations for online and blended learning:</u>

These AREOLA PR2 materials can be used in online, blended or face-to-face teaching. Teachers and trainers need to keep in mind that when these materials are used in online and blended learning, the case studies, group work or quizzes can be considered as good sources to encourage learner interaction and participation in the lecture. During virtual training, the interaction with and of participants should be focused. Trainees should be involved, e.g. by having cameras on, the trainer talking to the audience and discussing with them, having exercises, group work or quizzes together.

Annex

During the preparation of own AREOLA case studies, the consortium collected external and publicly case studies with Aerospace content. An overview of the collection is presented below.

Case studies on Aerospace for the PBF-LB Operator

1. Additive Manufacturing for the new A350 XWB
   - Origin: https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_sogeti_en.pdf

2. Future Ariane Propulsion Module: Simplified by Additive Manufacturing
   - Origin: https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_arianegroup_en.pdf

3. Advanced Manufacturing Process by EOS Optimizes Satellite Technology
   - Origin: https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_airbus_en.pdf

4. Certified for Universal Success: Additive Manufacturing of Satellite Components
   - Origin: https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_ruag_en.pdf

5. First Metal 3D Printed Primary Flight Control Hydraulic Component Flies on an Airbus A380
   - Origin: https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_liebherr_en.pdf

6. An Intelligent Strategy for Achieving Excellence: MTU Relies on Additive Manufacturing for its Series Component Production
   - https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_mtuaeroengines_en.pdf

7. Durable up to the Sound Barrier and Beyond
   - https://www.eos.info/01_parts-and-applications/case_studies_applications_parts/_case_studies_pdf/en_cases/cs_m_aerospace_vectoflow_en.pdf

8. 3D-PRINTED COAXIAL INJECTOR FOR A LOX/KEROSENE ROCKET ENGINE
    - https://www.small-launcher.eu/wp-content/uploads/M%C3%BCller-3d-printed-coaxial-injector-for-a-LOX-kerosene-rocket-engine-SP2018_176-Sevilla-2018.pdf

9. GE9X Additive Parts
    - https://www.ge.com/additive/sites/default/files/2020-08/GE9X%20Additive%20parts.pdf

10. HIETA Technologies AM aerospace applications examples
    - https://www.hieta.biz/wp-content/uploads/2018/09/HiETA-Brochure.pdf

11. LENS Blisk Repair Solution
    - https://optomec.com/wp-content/uploads/2014/04/Optomec_LENS_Blisk_Repair_Datasheet.pdf

12. Titanium high pressure hydraulic manifold for passenger aircraft
    - https://www.nrc.gov/docs/ML2033/ML20339A650.pdf

13. Laser Powder Metal Deposition Manufacturing of Complex Real Parts
    - https://docplayer.net/48458850-Case-study-laser-powder-metal-deposition-manufacturing-of-complex-real-parts.html

14. The innovation of an industry; using 3D printing to elevate aerospace production
    - https://www.stratasys.com/es/resources/case-studies/plyform/

15. Marshall Aerospace and Defence Group soars with 3D printing
    - https://www.stratasys.com/es/resources/case-studies/marshall-aerospace-and-defence-group//

16. Industry leaders increase competitiveness by reducing time, cost, and material waste with 3D printing
    - https://www.stratasys.com/es/resources/case-studies/idecwehl/

17. Airbus Gets on Board with 3D Printing Case Study Materialise
    - https://www.materialise.com/en/inspiration/cases/airbus-3d-printing

18. Principles of Directed Energy Deposition for Aerospace Applications
    - https://ntrs.nasa.gov/api/citations/20210000449/downloads/UTEP-Course%20-%20Principles%20of%20DED_Gradl_Jan2021.pdf

19. Potential occupational hazards of additive manufacturing
    - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6555134/#:~:text=As%20discussed%20in%20powder%20bed,to%20toxic%20or%20sensitizing%20materials.&text=Additionally%2C%20liquid%20binders%20may%20have,combustible%20and%20a%20potential%20irritant.

20. OVERVIEW OF DISPOSAL PROCEDURES FOR POWDER CONDENSATE WITHIN METAL POWDER BED FUSION
    - https://amgta.org/wp-content/uploads/2021/03/Overview-of-Disposal-Procedures-for-Powder-Condensate-Within-Metal-Powder-Bed-Fusion-Sintavia-2021.pdf

21. Product Assurance Overview of Additive Manufactured Components for Space Applications
    - C:\Users\johannsen\Downloads\EUCASS2022-4882.pdfhttps://www.eucass.eu/component/docindexer/?task=download&id=6587

22. Nondestructive Testing of Additive Manufactured Metal Parts Used in Aerospace Applications
    - https://ntrs.nasa.gov/api/citations/20180001858/downloads/20180001858.pdf

23. Guidance Notes for Metal Additive Manufacturing Certification
    - https://i.emlfiles4.com/cmpdoc/6/1/1/2/5/files/1016458_lrqa-guidance-notes-for-additive-manufacturing-certificationapril-2022.pdf

24. PERFORMANCE MONITORING AND CONTROL FOR AN ADDITIVE MANUFACTURING FACTORY - A CASE STUDY IN THE AEROSPACE INDUSTRY
    - https://www.designsociety.org/download-publication/39747/Performance+monitoring+and+control+for+an+additive+manufacturing+factory+-+A+case+study+in+the+aerospace+industry

25. Monitoring system for the quality assessment in Additive Manufacturing
    - http://impulsthermografie.de/QNDE2014-Proceeding_EN_V3.pdf

26. Post-Processing Techniques to Enhance the Quality of Metallic Parts Produced by Additive Manufacturing
    - https://mdpi-res.com/d_attachment/metals/metals-12-00077/article_deploy/metals-12-00077.pdf?version=1641261902

27. DESIGN AND MANUFACTURE OF A SAFETY CRITICAL AEROSPACE COMPONENT BY ADDITIVE MANUFACTURING
    - https://additivemanufacturinguk.org.uk/wp-content/uploads/2023/02/NCAM-Case-Study_EWIRA-TCT-Show-2018-PREVIEW.pdf

28. Renishaw reduces machining time for aerospace impeller manufacturer
    - https://www.renishaw.com/en/renishaw-reduces-machining-time-for-aerospace-impeller-manufacturer--42954

29. Metal additive manufacturing in aerospace: A review
    - https://www.sciencedirect.com/science/article/pii/S0264127521005633

30. Powder-bed additive manufacturing for aerospace application: Techniques, metallic and metal/ceramic composite materials and trends
    - https://www.diva-portal.org/smash/get/diva2:1316708/FULLTEXT01.pdf

31. Additive Manufacturing Trends In Aerospace
    - https://purpleplatypus.com/wp-content/uploads/2018/05/White-Paper-Additive-Manufacturing-Trends-in-Aerospace-Leading-the-Way-EN.pdf

32. Review: The Impact of Metal Additive Manufacturing on the Aerospace Industry
    - https://www.mdpi.com/2075-4701/9/12/1286

33. Operator Burden in Metal Additive Manufacturing
    - https://repositories.lib.utexas.edu/bitstream/handle/2152/89722/152-Elliott.pdf?sequence=2&isAllowed=y

34. Leveraging Metal 3D Printing & Advanced Design Software for Advanced Rocket Propulsion Development
    - https://velo3d.com/case_studies/leveraging-metal-3d-printing-advanced-design-software-for-advanced-rocket-propulsion-development/

35. Improving Critical Rocket Engine Performance with Advanced Metal AM
    - https://velo3d.com/case_studies/improving-critical-rocket-engine-performance-with-advanced-metal-am/

36. Recommended Guidance for Certification of AM Component
    - https://www.aia-aerospace.org/wp-content/uploads/AIA-Additive-Manufacturing-Best-Practices-Report-Final-Feb2020.pdf

37. Powder-bed additive manufacturing for aerospace application: Techniques, metallic and metal/ceramic composite materials and trends
    - https://www.researchgate.net/publication/331954114_Powder-bed_additive_manufacturing_for_aerospace_application_Techniques_metallic_and_metalceramic_composite_materials_and_trends

38. DRAMA helps AE Aerospace to develop short lead-time AM prototypes
    - https://ncam.the-mtc.org/media/bn1l0hhh/ae-aerospace-drama-case-study.pdf

39. Honeywell Aerospace assess the use of a new high temperature alloy (ABD®900AM) with its in-house laser powder bed fusion (L-PBF) metal AM technologies.
    - https://alloyed.com/alloys-case-study/metal-additive-manufacturing-for-high-temperature-applications-material-developments/

40. Sentinel Satellite Antenna Bracket
    - https://www.oerlikon.com/am/en/markets/aerospace/