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Blended Learning Guideline for Implementation

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1. Introduction

The aim of this report is to support future European training in Additive Manufacturing (AM) to be delivered with innovative blended learning methodologies, in alignment with the requirements of the International Additive Manufacturing Qualification System (IAMQS). The contents of this report include a comprehensive approach to blended learning methodology, point out the teaching methods that can be used in blended learning, as well as the added value of using blended learning in training.

Additionally, the report shows the AREOLA project results and its implementation in the IAMQS. By including theoretical materials and virtual training tools, tailored for PBF-LB operators in the aerospace sector, AREOLA is boosting the attractiveness of the IAMQS among different sectors. In addition, the AREOLA project increases the attractiveness of vocational training by broadening the scope of training, considering their specific needs and providing innovative training materials. The developed Extended Reality (xR) tools were validated by the learners during pilot activities, through a practical assessment and feedback questionnaires. Also, in order to validate the approach, the pilot activities included a comparison between hands-on and xR tools teaching methods.

Finally, a set of recommendations is presented, based on the lessons learned coming from the pilot activities developed in PR4 - Comparison between the different learning and teaching strategies. The report concludes with a step-by-step approach on how to transfer the AREOLA outcomes to other qualifications, providing a truly sustainable plan for the AREOLA project.

2. A Framework for blended learning

Traditional blended learning mixes two forms of learning, online learning and face-to-face learning, with the two forms of learning, merged didactically into one learning concept. In an ideal learning arrangement, both forms of learning are used optimally, for example to impart factual knowledge in a self-learning phase by means of online learning and then to deepen and apply this in practice in the attendance phase.

In response to the coronavirus pandemic, the European Commission published a proposal for a Council Recommendation on blended learning for quality and inclusive primary and secondary education in August 2021 [CELEX 52021DC0455, page 4]. According to this proposal, the blended learning definition has been extended and blended learning in formal education and training is when a school, teacher or learner follows the learning process with more than one approach:

- Combination of school and distance learning environment;
- Combination of different learning tools, which can be digital (including online) and non-digital, as part of learning tasks.

The replacement of practical exercises on the systems with xR tools chosen in the AREOLA project should therefore also be understood as blended learning, regardless of whether the training takes place in classroom form or online at different learning locations.

There are various teaching methods that can be used in blended learning:

- Face-to-face (traditional student-teacher relationship)
- Rotation (students move from one station/activity to the next)
- Flex (students determine their own learning path - the professor acts as a mentor)
- Gamification (with game elements: e.g.: students compete against each other and jump from level to level)
- Online lab (complete online learning to deepen knowledge)
- Self-blend (involvement of interested students in white papers, blogs, video tutorials, etc.)

Blended learning introduces innovative approaches to training, in addition, it is also a potential way of delivering training in a more flexible way, enhancing trainee experience while maintaining and guaranteeing quality. A summary of blended learning add-value in training is show in Figure 1 below.

Global Collaboration and Knowledge Exchange	Integration of Emerging Technologies	Optimizing Training Resources
- Blended learning breaks down geographical barriers. - Integration of diverse perspectives from international experts. - Facilitated by online platforms. - Enhances richness of training programs. - Collaborative approach ensures global relevance. - Aligns qualifications with recent advancements.	• Seamless integration of emerging technologies into training curricula. • Utilization of virtual simulations and interactive modules. • Helps professionals stay side by side with breakthroughs in AM processes, materials, and digital technologies. • Ensures practical, engaging, and reflective training. • Reflects the latest industry advancements.	• Optimizes utilization of training resources. • Cost-effective and scalable approach. • Strategic deployment of resources. • Ensures accessibility to a broader audience. • Opens opportunities for partnerships with industry leaders. • Leverages expertise to enhance training experience.

Figure 1: Blended learning added value in training

The approach pursued in the AREOLA project is to supplement specific aerospace training content in the general PBF-LB operator training programme and, if necessary, to be able to teach (parts of) the training online. This is where the xR tools are brought into play in order to be able to replace practical training elements with online lessons. The step-by-step procedure is shown in Figure 2 and can be found in detail in the PR1 report.

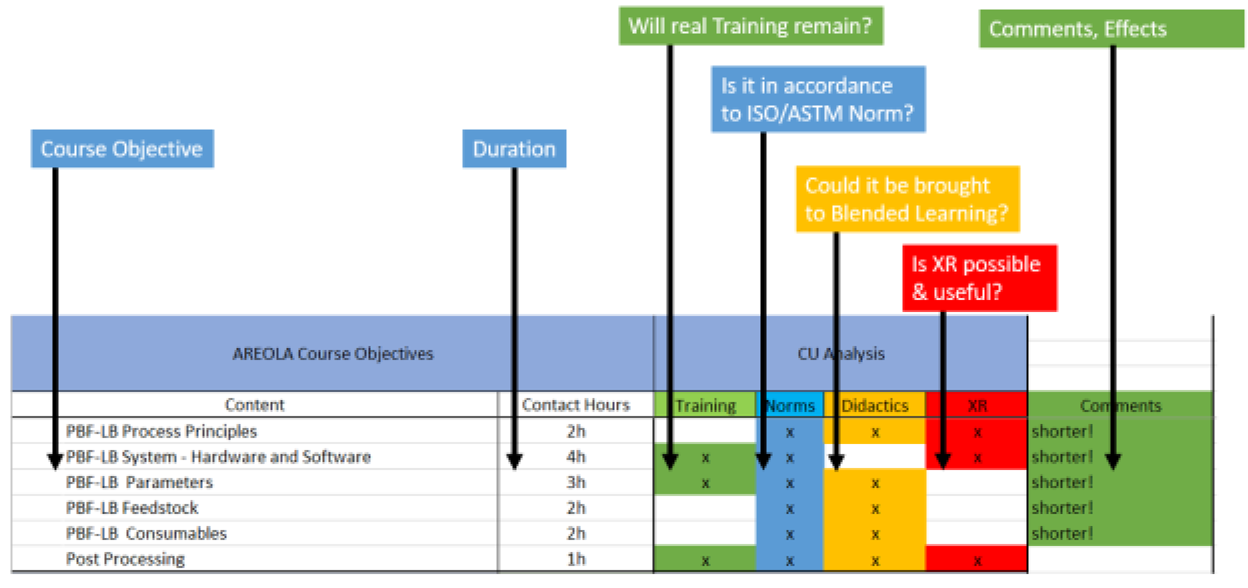

Figure 2: BL/xR Screening

Each learning content was assessed in terms of the following approaches that could be implemented, namely:

- Training (physical face-to-face training)

- Didactics (learning concepts such as eLearning)

- xR (extended (augmented and virtual) reality content)

In addition, the conformity of the respective learning content with the standard ISO/ASTM 52942 "Additive manufacturing - Qualification principles - Qualification of machine operators of laser metal powder bed fusion systems and equipment used in aerospace" was checked as far as this was possible on the basis of the available data. The tools can then be used to supplement flipped classrooms[1] / simulation and virtual (assessment) tools or problem-based learning, for example.

[1] The Flipped Classroom is an innovative teaching approach that reverses the traditional learning model, where teachers present and instruct during class. In a Flipped Classroom, students are provided with pre-class materials, which can include videos or readings, to review before attending classes. During class time, students actively engage in discussions, problem-solving, and the application of knowledge, with teachers serving as guides.

3. AREOLA objectives and its implementation

One of the motivations behind AREOLA project is to accelerate the digital transition in vocational education. To achieve this goal the AREOLA project developed online deployable theoretical materials and virtual training tools specifically designed for PBF-LB operators, particularly for those working in the aerospace sector. Two different stages were carried out: theoretical pilots and practical pilots, the latter using xR tools. During the implementation of the pilots, the main concerns were to guarantee compliance of the competence units and the procedures to deliver the training.

3.1. Blended learning in the International Additive Manufacturing Qualification System – State of the Art

The grounds for AREOLA project are based on the International Additive Manufacturing Qualification System (IAMQS). This system encompasses a range of qualifications tailored to different proficiency levels in the field of AM technologies which are firmly grounded in industry requirements and validated by experts. The AM Qualification System is managed by the European Welding Federation (EWF), and covers Metal AM Qualifications for Operators, Designers, Supervisor, Coordinator and Engineers, as well as one Polymer AM Qualification for Designers.

The Qualification System employs a modular structure organized into learning outcome units, which define the expected knowledge and skills trainees should acquire upon successful completion of the training courses. A single syllabus is established for each qualification level, complemented by a harmonised assessment and quality assurance system grounded in industry standards.

This harmonised system ensures that trainees receive the same qualifications regardless of the country where they undertake the training, fostering closer collaboration between training centres and AM companies involved in the System. The International AM Qualifications System comprehensively encapsulates all procedures and guidelines necessary to establish a quality assurance system for AM training providers throughout Europe. It integrates international training guidelines that may be developed or tailored based on feedback from stakeholders, including vocational education and training organizations, trainees, and the International AM Qualification Council.

Regarding blended learning, nowadays the IAMQS foresees that all theoretical competence units can be delivered in blended learning. The exception is for the assessment process, which must be taken in person.

To perform blended learning, the authorized training centres need to follow a set of requirements to guarantee the quality of the learning. These requirements are reflected in the guideline IAB – 195. This guideline has been prepared, evaluated and formulated by the working group “Education, Training and

Qualification" of the International Authorisation Board (IAB) of the International Institute of Welding (IIW) and it provides the approach using blended learning / E-Learning techniques. A main concern of this reference document is to guarantee that the quality of courses delivered in blended learning is equivalent to the one in classroom. For this end, the guideline IAB – 195 reflects the minimum requirements for the education, training, examination and qualification. The scheme below summarises the key points included in this guideline (see Figure 3).

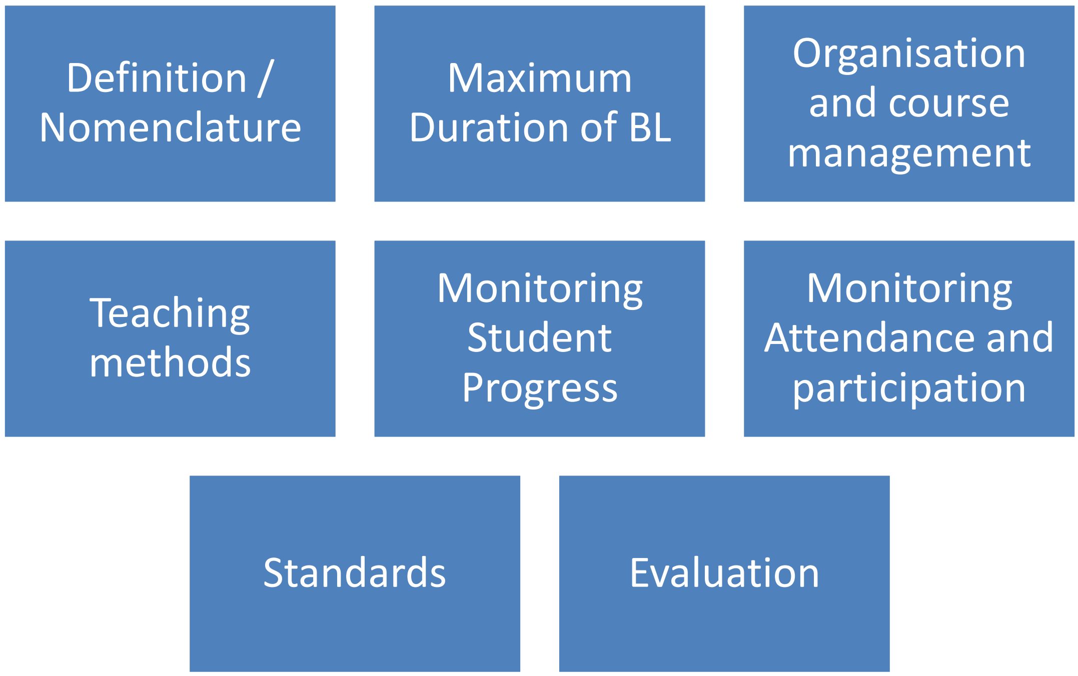

Figure 3: Key aspects of the guideline IAB – 195 on blended learning

Definition/ Nomenclature

This section guarantees that the scope of the guideline is clear for all users. Some of the definitions are listed below:

Assessment - Instrument to check the process of learning.

Blended learning (BL) - Term describing learning, that mixes various event-based activities, including face to face classroom presentations, and self-paced studies.

Classroom Training - General Classroom training (students physically present in class), Web conferencing, online seminars and video-conferencing are considered as classroom delivery.

Distance Learning (DL) - Distance learning is the education (including for e.g. e-Learning, video, interactive multimedia) of students who are not physically present at a school or training centre.

E-Learning (EL) - Educational technology is defined as "the study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources”.

Progressive Assessment - Various methods of assessment, including questionnaires and exercises, that are additional to the training material provided and are used to monitor student ‘s progress. Such assessments are completed by the student and returned to the training organisation for evaluation.

Maximum duration of blended learning

The duration of a Competence Unit (CU) is defined on the basis of the minimum requirements necessary to achieve the learning outcomes described. The CUs show the contact (teaching) hours to be devoted to achieving them. The recommended contact hours are distributed between lectures (A), assigned projects/exercises (B) and practical training in workshops (C).

According to the IAMQS guidelines, theoretical CUs can be taught in a BL context, using digital technologies in distance learning. In AREOLA, the innovation is regarding the use of these technologies in the practical training, allowing that parts of the practical training can be taught remotely, for example by using xR tools.

Organisation and course management

To use blended delivery techniques effectively, the training centres need specific resources and procedures to implement these courses in an acceptable and effective way. These resources and procedures include:

- a study plan / detailed layout for each course
- suitable training aids for blended learning
- procedures and material for the progressive assessment of students
- an effective management structure covering student supervision; electronic communication; internal examination procedures; distribution of course materials and student support.

In addition, the tools to be offered to students are:

- periodic evaluation of course materials and methods of delivery,
- procedures to ensure that the content of blended learning / e-Learning packages follows the guidelines for the appropriate grade of qualification.

Teaching methods

Blended learning can be delivered by following several teaching methods. These teaching methods comprise classroom delivery, laboratory and practical work and Blended Learning methods. They can be a combination of various options.

The courses can use an increased proportion of classroom training (over and above the minimum levels set out in the guidelines). The chosen teaching methods must be properly balanced in order to guarantee that the learning outcomes are equivalent to those achieved in a conventional classroom.

Monitoring student progress

In addition to self-evaluation, periodic assessments shall be carried out for each module in order to evaluate the progress of students. These assessments provide feedback to the training organisation to evaluate student progress. Some of the examples can be questionnaires or case studies.

Monitoring attendance and participation

The monitoring of attendance is mandatory. For attendance purposes, the trainee must attend at least 60% of the classes.

Training Standards

Training should ensure that the students have access to the applicable standards, if relevant with the scope of each item and as required by the relevant guideline.

Evaluation

The evaluation in blended learning is made of a number of questions per teaching hours for self-assessment. The implementation of the guideline, however, does not include the practical training. For the IAMQS, one of the limitations and concerns is how to guarantee that that the quality of courses delivered in blended learning is equivalent to the one delivered conventionally, including classroom and in practical training.

The qualifications in IAMQS are designed based on the industry requirements and constantly validated by experts. The detailed knowledge and the learning outcomes in the curriculum are aligned with the standards required by industry and the safest way to guarantee that the training is being delivered with the same standards, is a primary concern.

3.2 AREOLA proposal to implement blended learning in the IAMQS

AREOLA project set out to pilot whether training being delivered in blended learning matches the same requisites as the presential training.

The key conclusions drawn from AREOLA piloting report indicate that **incorporating the xR method into practical pilot training for PBF-LB machine operators is a viable strategy**. The method can be applied by exclusively utilizing xR for complex and risky tasks or by providing essential information to trainees before hands-on engagement with the actual machine. This approach aims to enhance safety, prevent accidents, and optimize time allocation by minimizing the need for delivering basic information during practical sessions. This indicates that a blended approach, combining xR technology with traditional training methods, can be beneficial.

The "xR and Hands-on method comparison report" developed in the Project Result 4, showed that **trainees usually acquire knowledge at the same level with these two methods**. Additionally, the trainees thought that the xR method is pedagogically appropriate in terms of **effectiveness, interactivity, encouragement to learning, and confidence-buildin**g. The method is eligible for use **across different age ranges and technological knowledge backgrounds**. Trainers also support these methods in terms of **interactivity, safety, and the effectivenes**s of xR materials in capturing trainee's **attention.**

There are several advantages to using this method. For example, the xR method allows for self-paced learning, the potential for remote training, reduction of time and cost in training, and prevention against harm or damage when encountering the machine for the first time. This perceived effectiveness and the recognition of several advantages are promising for the integration of xR tools in practical training.

However, despite its advantages, the method has some barriers. For instance, trainees need to familiarize themselves with the xR technology before starting the training. Moreover, the training environment should be well-organized, ensuring enough space for training, and finally, the xR tool itself should be built with good quality and resolution. These warnings should be considered by trainers who plan to deliver training through xR tools.

The success and effectiveness of the xR method in the practical training of PBF-LB machine operators can be generalized to inform a broader blended learning approach. The key takeaway is that **integrating immersive technologies, such as xR, into practical training yields positive outcomes.** The findings suggest that a blended learning approach, combining traditional methods with xR technology, can enhance training outcomes by **optimizing time,** increasing **safety, and providing a proactive learning** environment.

In light of the successful integration of xR technology in practical training, several insights emerge that can inform a more generalized approach to blended learning:

- Firstly, **recognizing the versatility of xR, training providers, across diverse domains, should consider incorporating immersive technologies into their blended learning experiences.**

- The xR method, whether exclusively used for complex tasks or for delivering essential information before hands-on engagement, **offers a promising model for combining traditional methods with cutting-edge technology**. Emphasizing safety, time optimization, and proactive preparation, as demonstrated by xR, should be integral components of blended learning strategies.
- Moreover, comprehensive training and guidelines are essential for learners to proficiently use emerging technologies. The **success of xR in providing self-paced learning, potential for remote training, and cost/time efficiency highlights the advantages that can be harnessed in diverse training scenarios.**
- While addressing challenges such as familiarization and environmental organization, the key takeaway is the need for a b**alanced, adaptable, and continually evolving blended learning approach** that leverages the benefits of emerging technologies to enhance overall training outcomes.

3.3 Recommendations for delivering Blended Learning using xR tools

In a basic sense, blended learning refers to the ability to complement traditional face-to-face training with remote learning, made feasible today by modern broadband internet networks. This has allowed anyone in the world to share audio and video with others, conduct presentations, share desktop content, grant control of computers to other individuals thousands of kilometres away, all in real time and with enhanced fidelity.

The AREOLA project started precisely from this reality, and developed pilot activities within its to assess how the concept of blended learning could be applicable to the field of additive manufacturing. This was based on the development and testing of digital content and extended reality (xR) applications with real people. In this sense, AREOLA has sought to act as a "rehearsal" for the potential of delivering traditionally face-to-face content through digital modalities. This achievement was made possible through the implementation of two kinds of pilot activities:

- Theoretical pilots: contents aligned with the competence units of the PBF-LB technology operator profile within the IAMQS system were developed and tested both remotely and, in some cases, in-person. This allowed for testing the ability to convey and deliver technical contents through digital means.

From this perspective, it is crucial to note that the value of these theoretical pilots wasn't solely about testing slide-based presentations remotely. The methodology of remote training and the ability to share audio and video from additional sources were significant (for instance, in some pilot activities, trainers could display real parts during the training by sharing video signals from their own cameras). In essence, **these methodologies enable certain levels of real-time creation/editing during the training sessions, moving beyond exclusive instructor-based teaching to a content streaming approach**.

- Practical pilots: these were based on the development of virtual reality applications, replicating and enabling the execution of operations in a virtual environment, that were previously achievable only in real settings.

These practical pilots hold significant intrinsic value, as they were built upon new virtual reality applications developed by AREOLA project partners. Previous examples in this field were scarce, thus encapsulating a highly exemplary value in demonstrating the ability to replicate practical operations in a virtual digital environment.

It is worth delving into this practical pilots experience in some detail, as it holds a highly innovative component, making its outcomes especially significant. The AREOLA project conducted significant work in its PR4 phase that can be considered highly relevant in assessing the impact of integrating digital resources for training in competencies with a prominent practical aspect. The results derived from this effort point in these directions:

- The results obtained from surveys conducted with individuals who participated in the pilot testing activities suggest that there **was no significant difference in performance between participants who received practical training and those who received xR-based training**. Both in the exam and in the evaluation questionnaire, participants using xR technology scored similarly to those receiving practical training. Furthermore, participants trained through xR reported higher satisfaction with the training and increased motivation to learn. These findings suggest that **xR-based training can be an effective tool to enhance professional training in additive manufacturing, providing a satisfactory practical learning experience for participants.**
- Additionally, considering that the xR applications were executed on standalone and low-cost hardware, it is evident that xR technology offers significant advantages in terms of accessibility and flexibility in practical training. **This technology enables participants to access training from remote locations and with more flexible schedules**. Moreover, xR-based training can provide a highly **immersive learning experience, potentially boosting knowledge retention and motivation to learn**.
- There's an additional value to training conducted through xR technologies: its capacity to complement traditional practical training, either used before or after it. In this sense, the potential of these technologies and applications to prepare an individual before their interaction with the real machine or, conversely, to allow the unlimited repetition of activities after the "real" contact is of immense value.

The results are clear, attributing **to xR technologies the ability to be real alternatives for virtualizing and delivering competencies remotely that traditionally require access to often costly equipment and, therefore, have been traditionally conducted in person.**

Given the above, it is evident that the **AREOLA project has marked a milestone in demonstrating the possibility of creating training schemes that reduce the dependency on physical presence, thereby favouring the implementation of blended learning systems.** The next step would be to consider how it's possible to evolve towards these systems within the framework of training and accrediting additive manufacturing professionals in a standardized manner. The model taken as a basis in the AREOLA project has been, from the outset, the one provided by IAMQS, in which the reference professional profile would be the "Metal Additive Manufacturing Operator Powder Bed Fusion - Laser Beam" profile. Like other profiles in this recognition scheme, it is primarily defined from a training standpoint by the competence units that an individual aspiring to be recognized with such a profile must complete. In the case of a PBF-LB technology operator, the definition of competence units is as follows:

COMPETENCE UNITS	**I MAM O PBF-LB**	
	Recommendend Contact Hours	**Expected Workload ****
CU 00: Additive manufacturing Process Overview	3,5	7
CU 15: PBF-LB Process	14	28
CU 16: Quality Assurance (QA) in PBF-LB	7	14
CU 17: Health, Safety and Environment (HSE) in PBF-LB	3,5	7
CU 18: Hardware, software and build file set-up for PBF-LB	14	28
CU 19: Monitoring and managing the manufacturing of PBF-LB parts	3,5	7
CU 20: Post-processing of PBF-LB parts	7	14
CU 21: Maintenance of PBF-LB systems	7	14
Subtotal (without optional CUs)	**60**	**120**
CU 48: Powder Handling	7	14
CU 49: Laser Beam Characterization	7	14
Total	**74**	**148**

Figure 4: Overview on competence units of the PBF-LB Metal Operator professional profile

This is a first level of definition, which at deeper levels breaks down into a more detailed definition of each competence unit, identifying different subjects, the recommended contact hours for each of them, the related job activities, and specifying their learning outcomes, divided into sections of knowledge and skills.

CU 18: Hardware, software and build file set-up for PBF-LB

CU 18: Hardware, software and build file set-up for PBF-LB	Recommendend Contact Hours
SUBJECT TITLE	
PBF-LB machine set-up requirements	4
Pre-build check list	3
Consumables, feedstrock & substrate	3
Build files	1
Work documentation	2
Practical implementation of HSE procedures (while fit and set up the machine)	1
Total	14
WORKLOAD	28

CU	EQF/EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Hardware, software and build file set-up for PBF-LB	4 Independent	Fit and set-up hardware, software and build file for PBF-LB	Verifying the PBF-LB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	14	28
			Preparing and verifying the build substrate and feed-stock conditions		
			Performing: build file loading, process preparation, process starts, in process observation and mal function detection and mitigation		
			Build observation		
			Following HSE procedures during machine and build file set-up		

Learning Outcomes - CU 18: Hardware, software and build file set-up for PBF-LB	
KNOWLEDGE	Factual and broad knowledge of: - Variables of PBF-LB and related operational conditions parameters. - PBF-LB equipment requirements. - Materials used for PBF-LB. - Type of files and work documentation. - HSE procedures under PBF-LB.
SKILLS	Prepare the machine for operation, according to the AM procedure specification Prepare the feedstock, build platform and the machine in accordance to the material being used Verify if the PBF-LB machine complies with the machine manufacturer and/or internal specifications Load files to PBF-LB machines Verify if the PBF-LB machines are working in accordance with the job specification, in terms of process parameters Comply with HSE procedures associated to PBF-LB machines Interpret technical information related to the PBF-LB process and machines

Figure 5: Guideline for competence unit 18

Of all these **elements** in the description of the different **competence units** that make up the profile, perhaps the section with the **greatest potential for analysis** under the perspective of blended learning is the definition of **skills** associated with **each competence unit**. This way the possibilities, pros, and cons of considering and developing tools that allow for effective application of blended learning in different cases can be evaluated.

Therefore, recommendations BL implementation on IAMQS arise from an analysis that has been conducted based on these principles, so that for each skill:

- A **numerical assessment** has been included on whether the skill could benefit or be acquired under a blended learning framework, rated on a scale of 1 to 5, where 1 represents minimal or no benefit, and 5 represents maximum benefit.
- Additional **comments** have been provided, offering reasoning and complementary insights to the numerical value given.

The evaluation is presented below, in a summarized form:

CU 21: Maintenance of PBF-LB systems						
Skills	Can benefit from a BL approach?					Comments
1. Change protective lens and clean the nozzle	1	2	3	**4**	5	The concept is simple and easily transferable through digital content, although direct visualization on a real machine enhances the ability to detect dirt present in the system.
2. Assess the need to perform maintenance operations in PBF-LB system	1	2	3	4	**5**	In a machine of this nature, most maintenance will be preventive, but the operator needs to know the events that indicate the need to anticipate such maintenance or perform corrective maintenance. This is a highly theoretical body of knowledge that can be acquired through digital content.
3. Perform maintenance operations in PBF-LB system	1	2	**3**	4	5	This skill encompasses a set of operations, which can be thoroughly identified through digital means. Executing these operations might involve checks at times but also manipulation of various elements, hence the complete acquisition of the skill through exclusively digital means might have certain limitations
4. Identify the consumables for the different machine parts	1	2	3	4	**5**	This skill is predominantly theoretical, making it entirely

						compatible with acquisition through digital means.
5. Report the need to execute specific maintenance	1	2	3	4	**5**	Refer to Skill 2 (the comment made about this competence is considered applicable).
6. Support other technicians during system maintenance	1	2	3	**4**	5	The body of knowledge required to acquire this skill can be extensive, but a good foundation is considered achievable through digital means.
7. Verify the cleanliness of the optic system	1	2	3	**4**	5	The concept is simple and easily transferable through digital content, although direct visualization on a real machine enhances the ability to detect dirt present in the system.
8. Verify if the optical system is working correctly	1	2	3	**4**	5	The operations for power checking and laser calibration can be acquired theoretically and are partially virtualizable. However, specific verification systems like EOS SMARTCAL may require the use of complementary hardware, meaning the complete details of its use and application may need to be gained through hands-on experience
9. Monitoring and calibration status	1	2	3	**4**	5	Refer to Skill 8 (the comment made about this competence is considered applicable).
10. Verify the level of wear of a mechanical component	1	2	3	**4**	5	Required checks are perfectly transferable through digital content, although specific verifications benefit from hands-on experience (e.g., checking the wear level of a recoater blade)
11. Verify the system gas flow	1	2	3	**4**	5	Required checks are perfectly transferable through digital content, although specific verifications benefit from hands-on experience (e.g., checking gas flow rates)
12. Adequate maintenance routines to the material type	1	2	3	**4**	5	The body of knowledge required to acquire this skill may be extensive, but it is considered that the basics can be acquired through digital means
13. Verify the condition and make use of the personal protective equipment	1	**2**	3	4	5	It's possible to acquire this knowledge theoretically through digital means, but its practical

						application requires a hands-on approach.
Recommendations on BL for this CU						
It's possible to acquire the entire knowledge base contained in this competence unit through digital means, but undoubtedly, most skills require a hands-on with a real machine to ensure that the student understands the operations, comprehends the risks, knows how to use personal protective equipment, etc.						

In summary, the AREOLA recommendations for practical and theoretical training are the following:

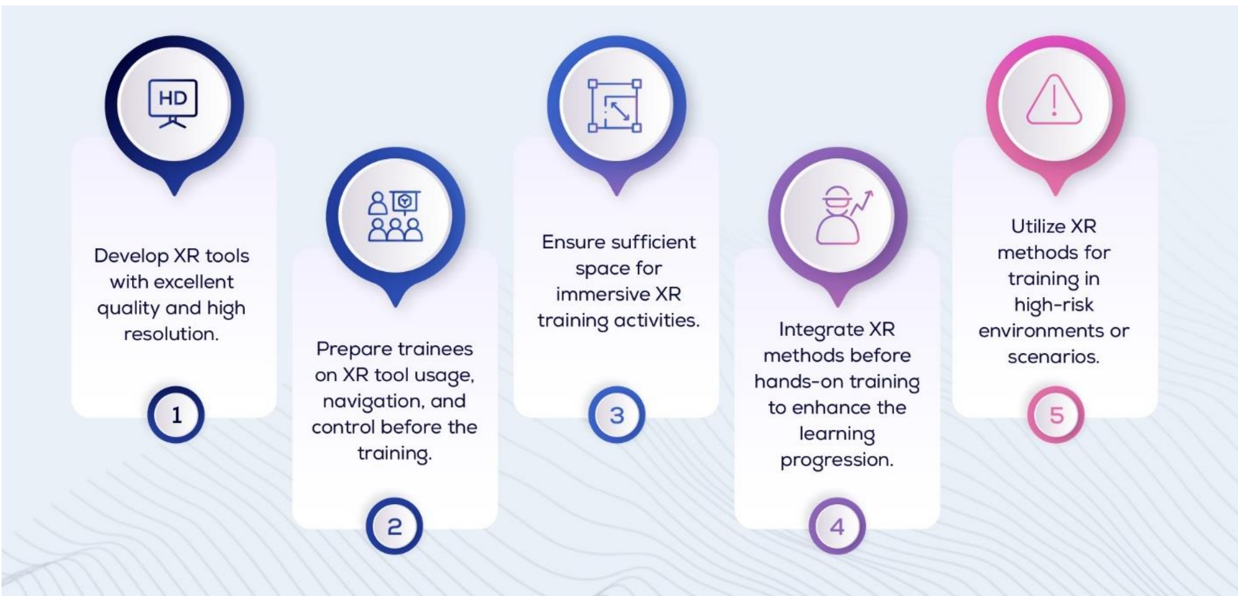

Figure 6: Recommendations for Practical Training

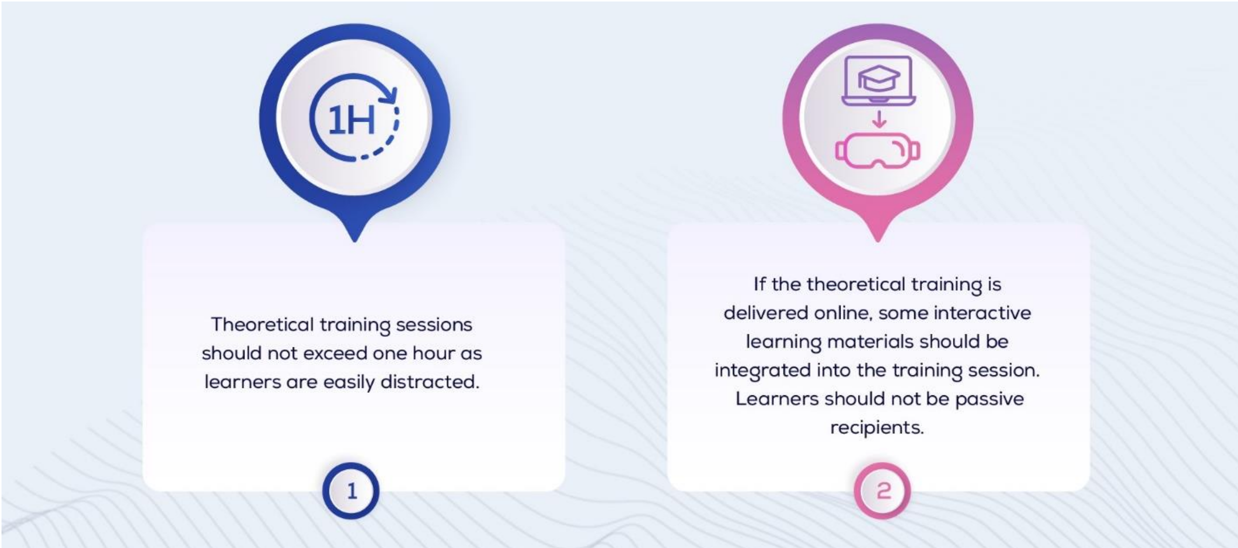

Figure 7: Recommendations for Practical Training

4. Transferability and sustainability

This chapter aims to provide an overview on the transferability potential of the AREOLA project results, ensuring their sustainability after the project reaches its end. The reason for exploring the transferability of AREOLA results to the IAMQS is based on the fact that this qualification system is present in ten countries, not only in Europe but around the world. The direct and assumed impact of this system in these ten countries is guaranteed, however, each country has a potential impact, based on each training centers that branch out of training network.

Therefore, a roadmap (Figure 6) has been designed, focusing on the description of the process of transferring the AREOLA know-how to other qualifications; the identification of possible qualifications suitable for the new approach; and an action plan for performing the transfer,l within the IAMQS. Thus, the IAMQS will be the main pillar of the AREOLA project for the transferability of its results, ensuring their continued implementation and applicability across Europe.

As a starting point, AREOLA addressed the international harmonized training guideline for the **Metal AM Operator PBF-LB**. Specifically, the development of xR tools for the implementation of the practical parts of training of **Competence Unit (CU) 21 Maintenance of PBF-LB systems**. Project partners LZH Laser Akademie GmbH (LAK) and IDONIAL already implemented (parts of) the qualification for the Metal AM Operator PBF-LB and/or others that contain CU21, which is transversal to the qualifications of the International Metal AM Operator Powder Bed Fusion – Laser Beam. Therefore, **the 1st step to ensure AREOLA project results transferability will be for these project partners to integrate the xR tools developed into their own training activities**, when delivering CU21.

As the IAMQS has already implemented a PBF-LB Operator curriculum and blended learning qualification path, the **2nd step will be to update the Metal AM Operator PBF-LB qualification by implementing AREOLA project results, in particular towards CU21 training, for the topics "Recoater blade replacement" and "Laser power measurement**". In order for this to happen, AREOLA project results proposal for integration within the IAMQS will be presented at the EWF General Assembly (GA).

The EWF GA represents a formal meeting where the EWF members make decisions on the development of the international harmonized system for education, training and qualification in the field of joining technologies and additive manufacturing. In the GA, the members also reflect on the innovation of the system, and for that, specialized workings groups are formalized. AREOLA outcomes will be present to the EWF's GA, in May 2024, where a vote will be held by the EWF members to assess if the existing Working Group (WG) will take on its results to transfer them to the existing PBF-LB Operator curriculum. After a further vote at the EWF General Assembly in October 2024, EWF members will vote to approve the integration of the updated guideline into the IAMQS. Therefore, the outcomes will be transferred to training centers that will use them in their activities.

Once the implementation of the AREOLA project results is completed for the training of the Metal AM Operator PBF-LB, **the 3rd step will be to replicate and transfer AREOLA results to other AM Operator Qualifications (DED-LB, DED-Arc, PBF-EB) within the IAMQS**. For this to happen, the same process described above will be applied. Therefore, once this plan has been presented and approved by the EWF members at the General Assembly, the defined WG will work towards using the analysis and research carried out in PR1 (Report on Validation Needs Analysis) and PR4 (Comparison between the different learning and teaching strategies); the transfer of the xR tools developed on PR3 (Development of VR/AR tools to deliver PBF-LB Operator Practical); and the methodology used on PR2 (Development of materials to deliver PBF-LB Operator Theoretical) for the theoretical online training guidelines. Once the proposal for the update of the Operator guidelines is accepted by EWF members at the next GA , it can be applied into the IAMQS.

All AREOLA outcomes (PR1 to PR5) have the potential to be transferred to other AM qualifications, as well as to other manufacturing sectors, such as welding, joining and related technologies. Due to the generalizable results of the AREOLA project, it will be possible to promote excellence in VET and improve quality assurance systems in VET if the project approaches used in PR1 to PR5 are then used as a benchmarking model for other AM processes and/or materials (e.g. for the automotive sector). Thus, the **4th step will be to transfer AREOLA results to other professional profiles of Metal and Polymer AM (IAMQS),** following the same process identified above for the Operators. Additionally, all project partners will ensure that appropriate steps are taken, in particular through the VET centers involved, to integrate this into their own training activities.

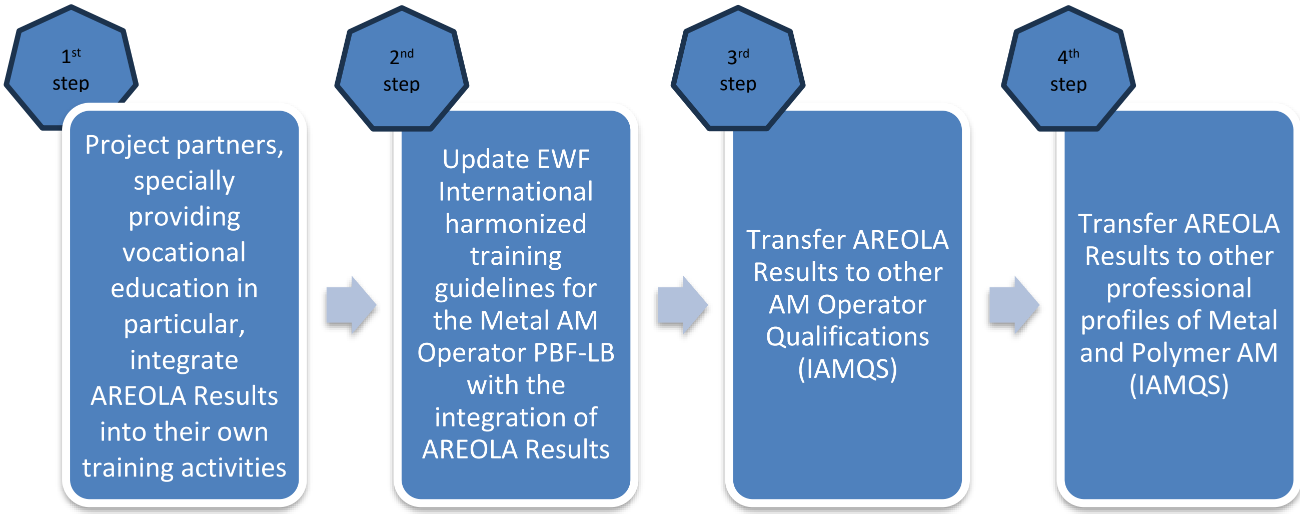

Figure 8: Description of the transferability process of the AREOLA know how to other qualifications

Overall, AREOLA project results will have a significant impact on the whole system, for the trainees, who will have access to online quality innovative training in an emerging sector, and for the VET providers, which will have access to innovative attractive training tools, highly impacting the overall quality of AM . Therefore, ensuring that AREOLA training materials and tools will be embedded and widely used in IAMQS, becoming a part of its qualification supporting documents and tools widely used across the European AM network of VET providers.

Moreover, the AREOLA consortium will reach out to European stakeholders in the VET fields, namely the European Association of Institutes for Vocational Training (EVBB), the European Association for the Education of Adults (EAEA) and the European Forum for Vocational Education and Training (EfVET), with which partners already have good working relationships, to ensure that they are familiarized with the AREOLA project results and their implementation potential.

5. Conclusions

In conclusion, this report serves as a vital resource to advance European training in Additive Manufacturing (AM) by driving innovative blended learning methodologies aligned with the requirements of the IAMQS. It offers a comprehensive exploration of the blended learning methodology, highlighting its teaching methods and value in training. Furthermore, the report delves into the objectives and the implementation of the AREOLA project within the IAMQS, showcasing its tailored theoretical materials and virtual training tools aimed at PBF-LB operators in the aerospace sector. The project's phased implementation, encompassing theoretical and practical pilots using xR tools, underscores its commitment to enhancing vocational education attractiveness. Through lessons learned from pilot activities, key recommendations are provided, paving the way for a sustainable transfer of AREOLA outcomes to other qualifications. This step-by-step approach ensures the lasting impact and legacy of the AREOLA project in shaping the future of AM training in Europe.

Annex.

Assessment matrix: applicability of blended learning methodologies to the professional profile “Metal Additive Manufacturing Operator Powder Bed Fusion - Laser Beam” (International Additive Manufacturing Qualification System)

Presented below is a comprehensive assessment of the applicability of Blended Learning (BL) methodologies to the competence units comprising the professional profile “Metal Additive Manufacturing Operator Powder Bed Fusion - Laser Beam”, as defined by the International Additive Manufacturing Qualification System (IAQMS).

CU 00: Additive manufacturing Process Overview						
Skills	Can benefit from a BL approach?					Comments
1. Distinguish parts produced by different AM processes	1	2	**3**	4	5	The differences between parts (real ones) manufactured using different technologies may be visible at first glance, but in many cases, they're subtle. Characteristics like roughness, textures, manufacturing marks, etc., are challenging to convey beyond high-quality photos/videos. However, within a blended learning perspective, there's the possibility for a remote instructor to have a sample set of parts to display on camera and provide various comments about them.
2. List the advantages and limitations of AM processes from a manufacturing process chain point of view	1	2	3	4	**5**	Discussing the advantages and limitations of AM technologies (in general and specifically) is essentially theoretical.
3. Name the applicability of different AM processes, according to the characteristics of each process	1	2	3	4	**5**	Exploring the applicability of different AM technologies is primarily theoretical.
Recommendations on BL for this CU						
CU00 is a highly theoretical competence unit, aiming to provide an overview of the concept of additive manufacturing, its applicability, advantages, and disadvantages, while presenting the different technologies capable of implementing this manufacturing concept. In this regard, the presentation of content can be effectively carried out under remote training models. The "weakest point" undoubtedly lies in exemplifying and differentiating parts made using different AM technologies. However, this can be partially addressed if the remote instructor can real parts to the students through a camera and streaming, while discussing the particular characteristics of each technology. It's important to note, though, that appreciating the most subtle differences might require students to						

physically touch real parts to comprehend all the nuances. Some details (roughness, marks, layer differentiation, etc.) may not be perceivable through a remote training.

CU 15: PBF-LB Process						
Skills	Can benefit from a BL approach?					Comments
1. Describe the PBF-LB systems, including the components and their functions	1	2	3	**4**	**5**	An PBF-LB equipment is a machine of certain complexity, with a large number of elements and subsystems, so while a theoretical approach is possible, the benefit of having access to a real machine is undeniable. However, the possibility of generating a virtual model of a machine, which can be manipulated by the student (for example, a walk-around that allows opening and closing various modules, viewing certain basic elements, etc.), can be a good substitute for the real machine.
2. Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables	1	2	**3**	4	5	It is entirely possible to obtain a fairly comprehensive understanding of the consumables used by the machine and general guidelines for their handling through theoretical approaches. However, the perception of risks and the specific aspects of their handling may require an approach that demands a presential component.
3. Recognise the PBF-LB parameters and the influence of their adjustment on the as built part	1	2	**3**	4	5	Understanding concepts related to process parameters is achievable through a theoretical approach. However, evaluating the effects of various parameters may require observing how the machine applies them (for instance, application patterns and laser path permutation between layers) or their impact on the parts (finishes, defects, etc.). These details are complex to replicate in a virtual environment or appreciate without physical parts.

4. Recognise the interaction of the process heat source with the feedstock	1	2	**3**	4	5	Refer to Skill 4 (the comment made about this competence is considered applicable).
5. Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock and application of the gases used in PBF-LB	1	2	**3**	4	5	Refer to Skill 2 (the comment made about this competence is considered applicable).
Recommendations on BL for this CU						
The competence unit 15 has a significant theoretical component, considering that acquiring each of its skills demands a knowledge foundation that can be perfectly obtained theoretically. However, within this competence unit, there are several aspects where the possibility of physically manipulating various elements, observing real locations and tools, examining manufactured parts to review the effects of parameters, etc., might advise physical presence. The availability of a comprehensive machine model for virtual interaction (as described in the comments for skill 1) would, in any case, be a fundamental support to become familiar with the physical characteristics of the machine and its accessory elements.						

CU 16: Quality Assurance (QA) in PBF-LB						
Skills	Can benefit from a BL approach?					Comments
1. Recognise the broader use of QA within engineering	1	2	3	4	**5**	This is a predominantly theoretical competence unit that can be fully acquired through digital means
2. Recognise the scope of the PBF-LB operator qualification within the AM industry	1	2	3	4	**5**	This is a predominantly theoretical competence unit that can be fully acquired through digital means
3. Support the qualification and requalification procedures of PBF-LB equipment	1	2	3	**4**	5	This competence unit is highly theoretical, although direct visualization of the equipment and facilities may be relevant to internalize the related processes and concepts
4. Identify the main procedures, equipment and their role	1	2	3	**4**	5	Refer to Skill 4 (the comment made about this competence is considered applicable).
5. Prepare test reports based on the requirements specified by the manufacturer	1	2	3	4	**5**	Although it has a practical component, it is mainly documentary, so it can be fully acquired through digital means.
6. Read a manufacturing plan	1	2	3	4	**5**	This competence is highly theoretical, although direct visualization of the equipment and installations may be relevant for internalizing the related processes and concepts

7. Compare geometry and dimensions specified in the technical drawings with the as built parts	1	**2**	3	4	5	The interpretation of a technical drawing has a clearly theoretical aspect, but the comparison with real parts is predominantly practical. This specifically cannot be replaced with digital training materials
8. Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part	**1**	2	3	4	5	The measurement of a part requires physical manipulation in all cases.
9. Identify problems in the as build parts distinguishing between imperfections and defects	1	**2**	3	4	5	Even if the remote trainer has a set of parts to showcase on camera, various issues can be subtle. Developing purely digital content that realistically reflects all possible defects is complex
10. Report defects suggesting either their removal with post processing operations, further inspection or part disposal	1	2	**3**	**4**	5	Although showcasing all defects might recommend presential training, the knowledge base to understand how to repair or address defects and finishes can be conveyed theoretically, making it highly compatible with a blended learning approach
Recommendations on BL for this CU						
Generally, Quality Assurance is a body of knowledge with a strong theoretical component, where fundamental concepts and methodologies can be entirely acquired through digital content. Some specific skills clearly require a practical approach (such as all measurement operations), while others can also benefit from the ability to 'touch' and verify real parts.						

CU 17: Health, Safety and Environment (HSE) in PBF-LB						
Skills	Can benefit from a BL approach?					Comments
1. Identify the main hazards and safety measures associated with PBF-LB systems	1	2	3	**4**	5	From an exclusive identification perspective, this skill can be acquired 100% theoretically and can also greatly benefit from the use of manipulable 3D models, around which certain risks (electrical, handling, etc.) can be identified. However, the ability to perceive risks associated with the handling of particulate powders or heavy elements depends on the student's prior experience with them, making a

						practical/presential experience potentially necessary."
Recommendations on BL for this CU						
The main concepts and information of this competence unit can be acquired through non-presential modalities, but the perception of 'real risk' and learning about the use of personal protective equipment is more complex to replace. Even if they could be digitized/virtualized, the actual procedures and sensations of PPE on the body cannot be replicated.						

CU 18: Hardware, software and build file set-up for PBF-LB						
Skills	Can benefit from a BL approach?					Comments
1. Prepare the machine for operation, according to the AM procedure specification	1	2	3	**4**	5	The fundamental aspects of machine setup for operation can be described and recreated in digital media, and virtual environments can even be created where the learner has to go through various basic operations. In this sense, it is undoubtedly complex or impossible to recreate all the details or sensations, but its value as a tool for internalizing the process before using a real machine is undeniable
2. Prepare the feedstock, build platform and the machine in accordance to the material being used	1	**2**	3	4	5	The use of digital media (even recreation through virtual means) has practical limitations when a high manipulative component is required, especially in operations that involve handling considerable weights
3. Verify if the PBF-LB machine complies with the machine manufacturer and/or internal specifications	1	2	3	**4**	5	This skills translates into the student being aware of the checklist that allows identifying whether a machine is ready to work or is operating within its operational range under suitable conditions. It is a skill that can be acquired mostly through theoretical means, bearing in mind that the verification itself demands the opportunity to use real equipment at some point.

4. Load files to PBF-LB machines	1	2	3	4	**5**	The manipulation and loading of files is an operation carried out through software, so the concepts and related mechanics can be acquired through digital means.
5. Verify if the PBF-LB machines are working in accordance with the job specification, in terms of process parameters	1	2	3	**4**	5	Refer to Skill 3 (the comment made about this competence is considered applicable).
6. Comply with HSE procedures associated to PBF-LB machines	1	**2**	3	4	5	The use and handling of personal protective equipment have a theoretical component (at least in terms of defining the required PPEs), but their proper use is an aspect that is difficult to convey without hands-on session
7. Interpret technical information related to the PBF-LB process and machines	1	2	3	**4**	5	The ability to observe how a PBF-LB machine generates real-time information is interesting, but most of the information and documentation requires a thoughtful analysis. Therefore, this skill has a high theoretical component and can be very well adapted to a purely digital training approach
Recommendations on BL for this CU						
Several aspects of handling or interpreting information generated by a PBF-LB machine involve a high software component, or require knowledge and understanding of theoretical contents, making them entirely transferable to a digital training environment. On the other hand, there is a highly evident manipulative component in this competence unit, which can be replicated to some extent through digital means. Ultimately, it will require the presence of the student in the machine's environment, manipulating its accessory elements, and associated PPE.						

CU 19: Monitoring and managing the manufacturing of PBF-LB parts						
Skills	Can benefit from a BL approach?					Comments
Load powder following mandatory safety procedures	1	**2**	3	4	5	The completion of this activity requires a theoretical understanding of procedures and safety measures, but its execution (due to the nature of the material) is difficult to simulate through digital means.
Apply HSE procedures when manufacturing parts	1	2	**3**	4	5	The implementation of safety and health measures is broad, encompassing general measures like ventilation, air conditioning, etc., to the use of nearly full-body personal protective equipment.

						The theoretical aspects of this knowledge can be acquired through digital means, but the practical application of many of these measures requires hands-on practice.
Interpret technical documentation related to the requirements of the as built parts	1	2	3	4	**5**	The requirements associated with the parts can vary, leading to documentation of measurements, tests, trials, etc. These concepts can be acquired through digital contents.
Identify the main reasons for failure during the manufacturing process	1	2	3	**4**	5	Most of the events indicating a malfunction can be interpreted from visual checks or the data generated by the equipment, making it highly possible to develop lists and descriptions of the most common issues and how to detect them. Some of the problems/defects may be more evident when visualized on a real machine, observing the process (or its data) over a period of time.
Prepare reports on the manufacturing process, including identified issues	1	2	3	4	**5**	This is a skill primarily theoretical and document-based, thus it can be acquired through digital contents.
Recommendations on BL for this CU						
Although it might seem surprising, monitoring and managing an additive manufacturing process require acquiring a certain amount of knowledge where the most relevant aspects are associated theoretical. Hence, a good portion of these skills can be acquired, at least partially, through digital contents. It's essential to bear in mind that, in any case, all those tasks involving manipulation or intensive in the use of personal protective equipment are not entirely replaceable by digital content. This is because they involve operations, details, or even sensations that cannot be perceived without direct experience						

CU 20: Post-processing of PBF-LB parts						
Skills	Can benefit from a BL approach?					Comments
1. Remove the as build parts and base plates from the machine applying the necessary HSEBlended procedures	1	**2**	3	4	5	The basic operation can be understood through a theoretical or virtual approach. However, the cleaning of powders, or the perception of the weight of parts and base plates (although the manipulation using a forklift might be transferable) is challenging to replicate.

2. Carry out simple manual preparation of the as built part for different post-processing methods	1	**2**	3	4	5	The basic operation is understandable through a theoretical or virtual approach, but the execution of the operation itself is complex without the use of real parts
3. Remove powder from the powder bed and parts following mandatory safety procedures	1	**2**	3	4	5	Refer to Skill 1 (the comment made about this competence is considered applicable).
4. Separate the as built parts from base plates distinguishing the base plate from the part based on the technical drawing and specifications using simple manual processes	1	**2**	3	4	5	Refer to Skill 2 (the comment made about this competence is considered applicable).
Recommendations on BL for this CU						
Knowledge of post-processing techniques applicable to parts manufactured using PBF-LB technology can be acquired theoretically (and therefore, through digital means). However, the actual execution of these operations may not be easily digitized or virtualized at the present time, requiring physical presence to fully acquire the skills.						

CU 48: Powder Handling						
Skills	Can benefit from a BL approach?					Comments
1. Complete technical documentation related to powders for metal AM	1	2	3	4	**5**	Powder documentation and traceability is somewhat a complex process. However, it is a highly theoretical body of knowledge, entirely transferable through digital means
2. Characterise powders according to instructions from the engineer	1	2	**3**	4	5	It is possible to acquire a basic understanding of characterization processes, but their application and the management of the generated information, despite having a theoretical component, may require hands-on experience
3. Ensure powder conditioning according to the AM Procedure Specification	1	2	**3**	4	5	Refer to Skill 3 (the comment made about this competence is considered applicable).
4. Control the reusability of powders	1	2	**3**	4	5	The reusability of powders is closely related to their treatment, characterization, and conditioning processes, so the comments included in skills 2 and 3 are applicable here as well.
5. Handle powders according to HSE procedures	1	2	**3**	4	5	The safe handling of powders relies on theoretical knowledge of risks and safety measures, but its

						application is hardly replaceable by digital or virtual means
Recommendations on BL for this CU						
The competence unit related to particulate powder handling allows for a significant theoretical knowledge acquisition through exclusively digital means. However, considering the nature of handling and characterization processes, it is advisable to include a practical, hand-on component in the training						

CU 49: Laser Beam Characterization						
Skills	Can benefit from a BL approach?					Comments
Safely carry out power measurements including power stability	1	2	3	**4**	5	The operations for checking power and laser calibration can be acquired theoretically and to some extent virtually, although specific verification systems (e.g., EOS SMARTCAL) require the use of complementary hardware. Therefore, the complete understanding of their use and application may need to be gained through direct hands-on experience
Safely carry out beam profiling in different areas of the build platform	1	2	3	**4**	5	Refer to Skill 1 (the comment made about this competence is considered applicable).
Use other measurement equipment to determine other Laser beam properties	1	2	3	**4**	5	Refer to Skill 1 (the comment made about this competence is considered applicable).
Carry out measurement in accordance with existing standards and/or internal specifications	1	2	3	**4**	5	Refer to Skill 1 (the comment made about this competence is considered applicable).
Recommendations on BL for this CU						
It is possible to acquire most or a significant part of the theoretical knowledge base required for laser characterization tasks through digital means. However, the practical application of certain procedures or methods may advise a hands-on experience						