DESTINE

European Design Technicians League

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European Metal AM Design Technician Training Guide for Teachers and Trainers

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Introduction

The following document supports the preparation of lectures and courses for the European Metal Additive Manufacturing Design Technician (EMAM-DT) within the International AM Qualification System (IAMQS), a professional profile developed in the DESTINE project 2021. It can also be used for the preparation of trainers of other professional profiles and qualifications.

This is a short version of the main guide for teachers and trainers and it includes information on the EMAM-DT guideline and the IAMQS, pedagogical principles and a case study, that can be used as example during the lectures with Planning, Case Study and Solution or as practical exercise for self-learning or assessment when only using the section “Case Study or Practical Exercise” of the case study. The short guide is available in serveral languages: English, Italien, Portuguese, Spanish and German.

1. The European Metal Additive Manufacturing Design Technician (EMAM-DT) qualification standard in the context of the International Additive Manufacturing Qualification System (IAMQS)

1.1. The International Additive Manufacturing Qualification System (IAMQS)

The IAMQS is a qualification system created in 2018 with contributions from Industry representatives, managed by the European Federation for Joining, Welding and Cutting (EWF), that addresses a general concern: the challenge of European Education and Training providers to swiflty reply to Additive Manufacturing (AM) Industry's skills needs and mismatches, to cope with the rapid changes of this key enabling technology.

The IAMQS is currently comprised of eleven international Qualifications focused on Metal AM materials, ranging from Metal AM Operator and Metal AM Supervisor (aligned with an Independent proficiency level, consistent with EQF[1] level 4) to Metal AM Coordinator, Metal AM Process Engineer and Metal AM Designer (aligned with an Advanced proficiency level, consistent with EQF level 6).

It is is rooted on a strong and transparent Quality Assurance System applied with the support of Authorised Nominated Bodies for AM (AM ANBs). This quality assurance system allows the qualifications' harmonised implementation by EWF Traning Network from 46 countries worldwide. This harmonization implies that all Qualifications are implemented by Approved Training Bodies for AM (AM ATBs) in the same way, based on specific guidelines, and that students are assessed under the same conditions, irrespectively of the countries of those AM ATBs.

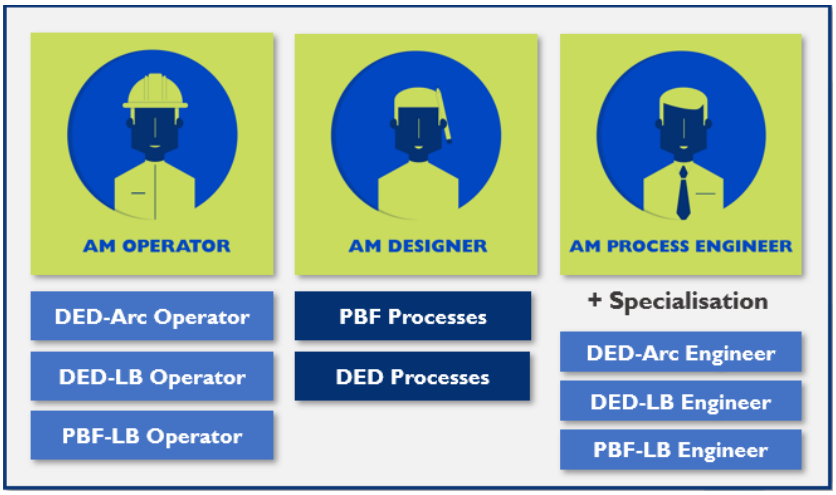

Figure 1 *Existent specializations for Metal AM Operator, Metal AM Designer and Metal AM Process Engineer Qualifications (IAMQS)*

[1] European Qualifications Framework (available on https://europa.eu/europass/en/european-qualifications-framework-eqf). EWF has its own Proficiency Levels, recognized by Industry at European level and aligned with EQF descriptors.

To develop its Qualifications and ensure their quality, IAMQS works closely with representatives from AM Industry representatives from Vocational Education and Training (VET) providers and Higher Education institutions and other individuals and organisations that are part of this wide ecosystem.

Only this way can the IAMQS ensure that all its Qualifications are recognised by Industry, both at European and international levels (as they reply to real Industry's needs and are aligned with its requirements), while addressing different levels of skills through the implementation of innovative pedagogical approaches aligned with current European education policies that promote Qualifications' transparency and the mobility and professional success of students.

1.2. The System's Modular Approach

The IAMQS uses a modular aproach which means that all its Qualifications are comprised of Competence Units, organized in Learning Outcomes defined in terms of knowledge and skills, to be acquired by students after succesfully accomplishing the Competence Units, individually taught, assessed and validated.

This modular approach brings an added value to AM ATBs, to students attending Qualifications and ultimately to companies:

- ✓ One single Competence Unit can be common to different Qualifications (cumulative system);
- ✓ The System promotes individual learning pathways by allowing each Competence Unit to be individually validated;
- ✓ Students can easily progress within the System by:
  - Accessing other Qualifications
  - Accessing higher and lower levels Qualifications.
- ✓ Companies benefit from "fit-to-purpose" Qualifications/training courses.

Also VET providers and HE institutions benefit from IAMQS and its Qualifications, as these represent an opportunity for addressing tecnhological contents and emergent technologies required by the AM sector. EWF Qualification Framework (i.e. Proficiency Levels) ensures transparency to all IAMQS Qualifications, allowing the recognition and linkage to National and European Qualification Frameworks, which facilitates their integration at National level.

1.3. Methodological approach for designing Competence Units

The IAMQS uses a specific methodological approach for designing CUs that implies the use of a common terminology to all its Qualifications, hence their harmonised implementation across AM ATBs. It also allows to structure the Competence Units using a "top-down approach", having Professional Profiles as a starting point for their design.

After defining the Professional Profile to be addressed by the Qualification/Training Course, the path is:

- to identify the job functions that are inherent to that professional occupation and their respective job activities;
- to identify the required knoweldge and skills and formulate the Learning Outcomes of the Competence Unit.

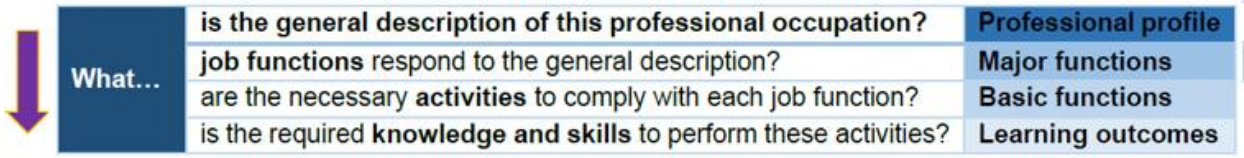

Figure 2 *EWF's methodological Top-Down Approach*

There are two types of Competence Units within IAMQS: functional and cross-cutting.

Functional Competence Units are the ones that directly address at least one job function from the Professional Profile.

FUNCTIONAL

Figure 3 *Structure of a Functional Competence Unit*

Cross-Cutting Competence Units are structured into Learning Outcomes that can be mobilised transversaly in several job functions and activities within the same Professional Profile or among different Professional Profiles:

CROSS CUTTING

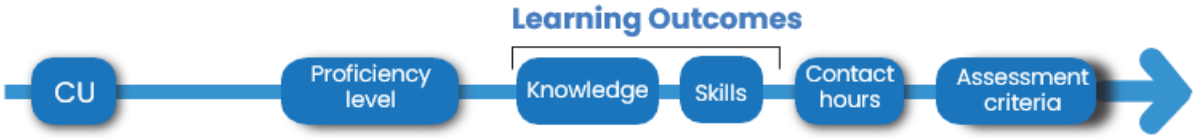

Figure 4 *Structure of Cross-Cutting Competence Units*

1.4. The European Metal AM Design Technician (EMAM-DT)

The concept behind DESTINE project was the need to attract young people to the AM field by creating a new qualification, designed in line with EQF level 4 (corresponding to Independent proficiency level from the EWF Qualification Framework): the European Metal AM Design Technician.

This Qualification was designed by implementing the above-mentioned IAMQS' modular and methodological approach for designing Competence Units. Thus, DESTINE partners identified the Professional Profile of a European Metal AM Design Technician: *this professional is someone who executes designs of Metal AM parts for Direct Energy Deposition (DED) and/or Powder Bed Fusion (PBF) Processes, develops solutions on basic and specific problems related to design of DED and/or PBF parts and contributes to projects in a teaming environment*.

From this point onwards, DESTINE partners identified the **job function** (*execute the design of parts for Metal AM Processes*) and required job activities of a Metal AM Design Technician:

- ✓ Create new (or redesign existent) models using CAD tools, based on the instructions provided by an AM Designer;
- ✓ Derive production drawings, the corresponding parts lists and their structure;
- ✓ Contribute to projects in a teaming environment.

Based on all these elements, DESTINE partners reached a decision on the **access conditions** an applicant must comply with to attend the European Metal AM Design Technician qualification:

- ✓ Skills in using 3D CAD tools and EQF level 2 in technical areas, or
- ✓ VET diploma in technical areas, or
- ✓ Comparable professional experience of at least 2 years.

1.5. EMAM-DT within IAMQS

One of the purposes of DESTINE project is the integration of the EMAM-DT qualification within the IAMQS, after its validation by the International AM Qualification Council.

This progression is possible due to the fact that there are common Competence Units (CUs) and common topics addressed by some CUs among the **EMAM-DT qualification standard** and the **Metal AM Designer for DED** and **Metal AM Designer for PBF Qualifications**.

The IAMQS Qualifications implies the revision of EMAM-DT qualifications, which will then have two levels of complexity: one for EQF level 4 (addressed by the EMAT-DT) and the other for the EQF levels.

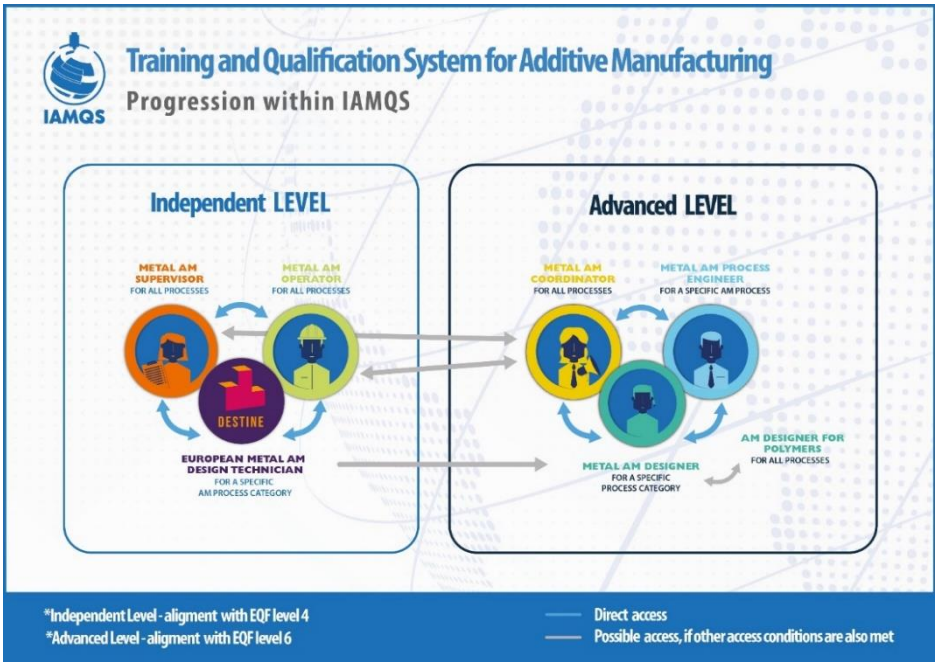

Figure 5 *The EMAM-DT within IAMQS: Progression from the EMAM-DT Qualification standard (Independent Level) to Metal AM Designer (Advanced Level)*

Thus, in order to progress from the EMAM-DT qualification to the Metal AM Designer Qualifications, the student must have successfully accomplished the qualification (or at least some of its Competence Units, including CU00) and accomplished an Engineering degree academic graduation, as the entry requirements to access to a Metal AM Designer Qualification require that applicants have an Engineering level degree[2].

There are indeed overlapping areas of activity, where it is important to understand when the role of one professional profile ends and the other begins. The following table (Table 1) allows to understand the level of expected autonomy of the Metal AM Design:

Descriptor of the Proficiency/ EQF level	Knowledge	Skills	Autonomy
	Metal AM Design Technician (DESTINE)		
Independent / EQF level 4	Factual and theoretical knowledge of the theory, principles and applicability of metal Additive Manufacturing design for DED/PBF processes	Fundamental cognitive and practical problem-solving skills required to design parts to be manufactured by DED/PBF Metal Additive manufacturing processes, under simple and specific conditions	Self-manage DED/PBF processes' simple design projects. Supervise routine tasks and similar function workers, as well as take responsibility for decision making in basic DED/PBF processes design applications
Advanced / EQF level 6	**Metal AM Designer for DED Processes Metal AM Designer for PBF Processes**		
	Advanced knowledge and critical understanding of the theory, principles and applicability of metal Additive Manufacturing design for DED/ for PBF processes	Advanced problem-solving skills including critical evaluation and design thinking, allowing to choose the proper technical and economical solutions, when designing parts to be manufactured by DED/PBF metal Additive Manufacturing processes, in complex and unpredictable conditions	Manage complex DED/PBF processes design projects, taking responsibility for decision-making in unpredictable DED/PBF processes design applications.

Table 1 - EMAM-DT vs. Metal AM Designer for DED/ for PBF Qualifications' Descriptors

[2] IAMQS is a Qualification System that provides professional training to its students through its qualifications, not academic training.

2. Principles of learning

2.1. Introduction

Firstly, it is important to have some concepts very clear:

Learning:
Learning is the process of acquiring new, or modifying existing knowledge, behaviours, skills, values, or preferences.

Education
The word education means to gain general theoretical knowledge, and this may or may not involve learning how to do any specific practical work, task, or skills.

Training
Training usually means the act of being prepared for something, of being taught or learning a particular skill and practising it until the required standard is reached.

2.2. Principles of learning

2.2.1. Module Objectives

Once this module is completed the trainer should be able to:

- Identify the key points of effective learning.
- Study elements that promote and inhibit effective learning.
- Evaluate the impact of principles of learning for practical teaching.

2.2.2. What is learning?

In terms of the most basic sense, learning involves the acquisition of new knowledge, skills and attitudes that result in some change in our ability to do something.

2.2.3. How do we learn?

There is a lot of information and studies about how we learn. An interesting starting point is to ask yourself this question: *How have I learnt in different learning situations?*

The answer is probably one of the following: *I attended a course; I asked a colleague; I planned it; I did some reading and research; I tested the information through trial and error; I practiced over and over*.

Acquiring relevant knowledge

The key process in knowledge acquisition is memory. The acquisition of some knowledge is involved in all learning, although the degree of this could vary depending on what is to be learned. Learning a new language, for example, requires much knowledge acquisition. Even so, an effective performance in skill-based activities like playing basketball requires the acquisition of important knowledge such as the rules of the game.

Thinking for understanding

It is necessary that learners make sense of what they have learnt and know how, when, and where to use this knowledge. Understanding the acquired information is essential to effective learning in most cases. What is learnt through memorisation would have little use and is prone to be soon forgotten without understanding.

Doing

Learning is often for the practical purpose of developing competence in an activity. This could be recreational, such as learning to play the guitar, or work related, such as learning to use a new software. Learning in these situations involves actually doing the activities, and repetition and practice over time is required to achieve improvement in performance.

These three components of learning (acquiring knowledge, understanding, and doing) do not occur as separate processes in real situations, though they are dynamic and synergetic for the success of the overall learning process. The acquisition of appropriate knowledge, good understanding and doing makes possible the development of competent performance over time.

2.2.4. Factors affecting learners and the learning process

The model described before can be applied to all learning and is a useful tool for planning instruction, but there are other factors that affect the actual process of learning for students. For example, if you think about the factors that have influenced your own learning, you will probably point out some of these:

- Motivation.
- The relationships you have had with teachers and peers.
- Your access to resources and time limitations.
- Your mood and situational factors.
- Your former learning in a given area.
- How you were taught.
- How relevant you perceive the learning to be.

The most important thing is that this list reflects that beyond an intellectual process, learning is a social and emotional one. The trainer must constantly bear in mind the next seven important principles of learning for the development, planning and delivering of the lessons that will be taught.

Principle 1: Utilise and stimulate the senses

Our five senses stimulate mental activity. Recent research suggests that each sense contributes the following percentages to our learning:

The possibilities of a successful learning increase with a greater combination of the senses that are stimulated in learning. For example, it is estimated that we learn:

10 %	Of what we read
20 %	Of what we read

30 %	Of what we see
40 % 50% 70 %	Of what we see and hear Of what we discuss Of what we experience
90 %	Of what we teach

It is essential to engage students in thinking, questioning, and doing real work activities to promote effective learning.

Principle 2: Recognise the learning curve

Despite learning is a continuous process, it does not advance at the same rate. For example, when you start to learn something new, it is common to observe a little progress at the beginning followed by a burst when you seem to learn quite a lot quickly. This is the moment when you are consolidating what you have already learned. A sustained effort is the key to achieve a new learning spurt.

It is important to help students to be conscious of these spurts and plateaus in their learning. This will prevent them to give up and maintain their confidence and motivation when experiencing plateaus in learning.

Principle 3: Do not abuse the attention span

Attention plays a central role in learning. With a deficient attention, learning is likely to be partial and ineffective. This results in important implications for teaching, it clearly shows that if the instructor talks for long periods with a lack of opportunities for student participation, those lessons are prone to be ineffective as a method of teaching.

Principle 4: Encourage the effective use of memory

We have seen before that the acquisition of knowledge is a key piece of effective learning. Both memorization and understanding knowledge are required.

a) <u>How memory works</u>

It is useful to think of our memory systems as the owner of two connected components: a short-term memory system (STM) and a long-term memory system (LTM).

The acquisition of knowledge relies on the effective transfer of information from STM to LTM. To achieve this transfer, it is essential that the information:

- Is meaningful (makes sense to the learner).
- Is in manageable pieces (around seven bits).
- Is organised.
- Is sufficiently rehearsed (repeated a number of times until easily recalled).

b) How forgetting occurs

Among the theories regarding forgetting, the most important for our purpose as instructor is that "over 60% of factual information will be lost within 48 hours if there is no subsequent rehearsal or review of what was learned". It is more difficult to forget skills and understanding. The chances of information established in long term memory increases with the more information reviewed in the first day or so after it is "learned".

c) Implications for teaching and learning

It is important to make students conscious of these basic principles of memory since this will prevent them of making the typical mistake of trying to memorise too much in a short time. Teachers must recognise that if they speak for long periods, there is a risk that little information will actually be memorised. Keeping information well organised and allowing students time to digest the content (either with activities or through question an answer sessions) is crucial to achieve an effective learning.

Principle 5: Try to motivate students in their learning

We have continuously observed that motivation is essential for effective learning. A student that is interested in what he/she is learning is a student who can learn effectively and independently.

Principle 6: Accommodate different learning styles

There are several proofs to suggest that each of us has his/her own characteristic ways of processing information, feeling, and behaving in learning situations. This implies that while all of us learn through acquiring knowledge, understanding, and doing, we have different preferences and approaches in terms of how we perform these activities.

- Visual → seeing pictures, words, diagrams
- Auditory → listening to explanations
- Kinesthetics → actually doing the activity

There are important implications in different learning styles and modality preferences for the ways in which we teach. This implies the need to involve the variety of senses and provide many different ways in which learners can go about learning.

Principle 7: Ensure effective feedback in the learning process

Feedback is crucial to achieve an effective learning in the following important ways:

- Feedback identifies the present state of learning.
- Feedback underlines what needs to be learned and suggest how to proceed with such learning.
- Learning can be monitored by feedback, which helps to diagnose problems quickly and find effective solutions.
- Positive reinforcement for learning is provided by feedback.

The use of expert feedback and guidance from the instructor may prevent many students to lose their motivation and fail in their learning.

Key tips in giving feedback:

a) Give feedback sooner, rather than later
b) Incorporate the positive (where possible)
c) Use feedback as two-way process

2.3. Conclusion

Specific implications for the practice of teaching have also been identified. In the next units, you will see how many of these principles are incorporated into the planning and delivery of teaching.

Do not forget that learning is a complex process and is influenced by many factors. Besides, each student has his/her own personality, motivation, and concern. Our role as instructors is challenging and rewarding since we try to understand both the uniqueness of each individual we teach and the general processes of learning. We are constantly learning about how best to help our students learn in the most effective ways for them.

3. Lessons planning

3.1. Introduction

"Someone who plans lessons develops well-founded ideas about what should happen in the lesson and why. In the lesson plan, these considerations and results are put into a written, perhaps also pictorial form that makes them easily and coherently comprehensible to third parties" (Esslinger-Hinz/Wigbers/Giovannini et al. 2013, p. 11).

As the quote makes clear, lesson planning is a complex process. Through a lesson outline, you write down the considerations and results you have made in the process. A lesson unit presented in this form fulfils different functions:

1. Basis for planning and for multi-perspective consideration.

2. Flowchart with further indications and methods.

3. Basis for analysis and reflection.

4. Communication medium to explain the process to others.

5. Exercise to develop own procedures

3.2. Goal of this elaboration

After reviewing this paper, you should have the ability to:

- Create a structured training plan in the area of additive manufacturing.

- Reflect on the learning process.

- Design a learning outcome assessment.

- Prepare the training room and training media appropriately for these training topics.

3.3. Preparation

Before you start planning a training, you should think about a few important things as an instructor. A lesson plan is a written document that specifies how you want to create a lesson using these five elements:

1. What learning objectives do I want to achieve with this training?

2. What learning content should be conveyed in this context?

3. Which teaching methods do I want to use?

4. Which teaching and learning aids are available to me?

5. In which form should the learning success control take place?

3.3.1. Learning objectives

The goal of teaching is to promote and develop the students' competence to act. The goal, however, is not to bring about an arbitrary change in behaviour, but a specific one. Therefore, an essential point of a lesson design is to specify learning objectives as precisely as possible. According to Mager, this is "a purposeful

description of goals (...) that succeeds in communicating the teaching intentions to [the reader]. A good description of goals also excludes as many possible misinterpretations as possible" (Mager 1972, p. 19).

3.3.2. Learning content

The learning content is the knowledge you want to impart during a session. This knowledge focuses on the understanding of a topic or underpins a skill that the participants should subsequently learn.

The greater the knowledge or understanding towards the subject matter taught, the more effective the teaching or training will be. It is not enough to simply know a topic and how to perform a task. You need a framework or structure in which to embed the knowledge.

It is important to follow a common thread that organizes the content and thereby supports a group's learning. It often helps to first identify the key concepts, principles, and models that you want to teach.

3.3.3. Teaching methods

Teaching methods are strategies used to help learners understand the content of the lesson and develop the skills needed to achieve the learning objective. The most popular and therefore most commonly used methods are explaining and demonstrating. However, these are only truly effective when supported by other methods that encourage learner interaction and participation.

The following graphic shows how effectively certain learning channels convey learning content, or how well it can be processed by learners. It is therefore advisable to take this into account when planning your lessons.

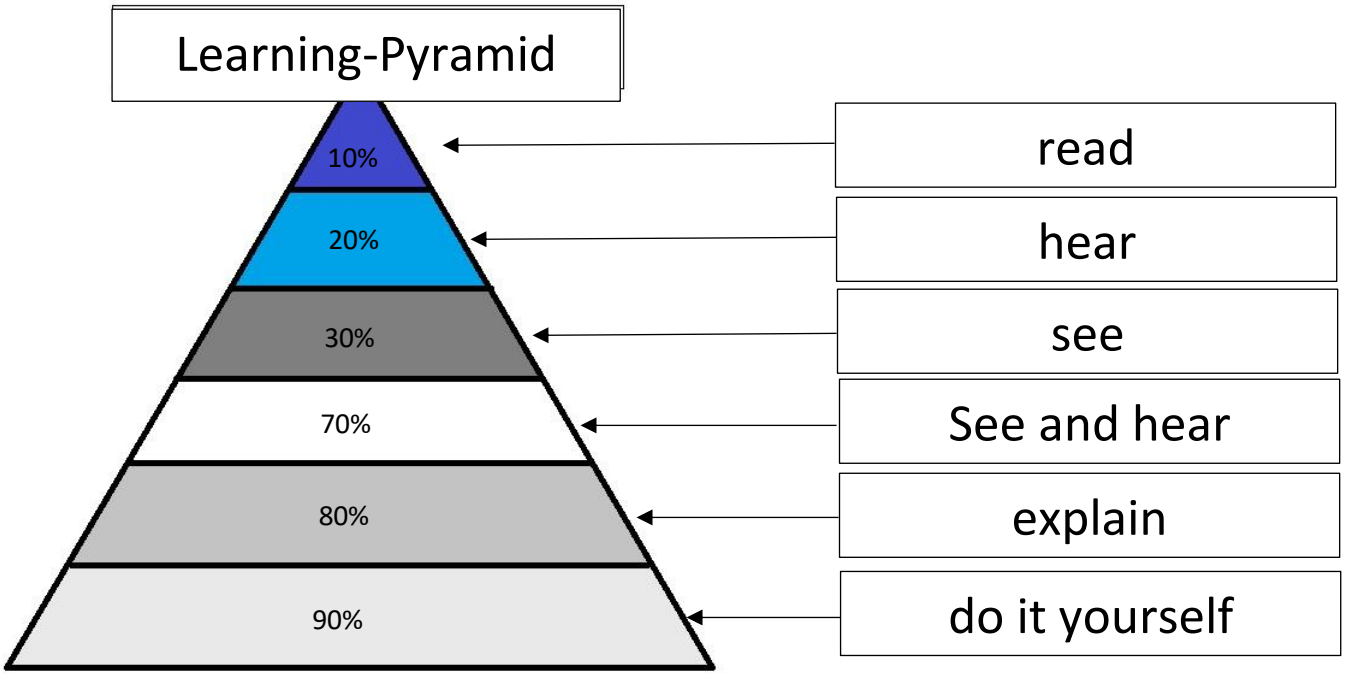

Figure 1: Learning-Pyramid (Vgl. Engelbert und Dachrodt 2014)

3.3.4. Teaching and learning tools

Teaching and learning tools refer to the teaching aids and resources that are to be used in the teaching unit to support the intended learning process. These include audio-visual aids, IT applications, tasks for learners, and handouts. Teaching and learning tools are often used in conjunction with different methods.

You should always make sure that your teaching/learning materials are well prepared and appropriately support your training.

The best-planned lesson may be ineffective if other important planning principles have not been fully thought through. On many occasions, speakers have planned specific activities for a lesson only to find that the training area does not have the necessary realities.

Preparation of the teaching room

Make sure the training area or room can comfortably accommodate the number of participants and is set up to fit the methods and activities you plan to use. In some cases, however, you may not be able to organize the room arrangement well in advance of the training, but it may happen just before. It is therefore advisable to arrive at the training room in time to make possible changes and check facilities. Do not use methods that would exceed the capacity and conditions of the room.

The learning Group

If you have to teach a completely unknown group, gather as much information as possible beforehand. Apart from knowing how many people will be attending the training, you should also determine what the prior knowledge in your training area is.

3.3.5. Learning assessment

Learning assessment is something that is often seen as assigning grades and is done at the end of a course, not in each session. However, these checks should also be an ongoing process to determine what and how individuals are learning and to provide a guide to the pace and nature of instruction. It is also a valuable source of feedback for learners, enabling them to monitor their own learning, both in terms of what they have achieved and how they can develop the skills they still need to achieve. Ensure that assessment is scheduled into a course, whether for formative (learning development) or summative (performance measurement for grading) purposes, or both.

3.4. Evaluation

Evaluation is one of the best ways to improve an area of performance and teaching is no exception. It may be useful to leave some space on your lesson plan for later evaluative comments.

When planning lessons, you can then refer to reflections or suggestions you made during the evaluation of previous training sessions.

It is worth spending some time thinking about "what went well" and "what didn't go well" in your sessions. Make any necessary notes on your lesson plan. Experience shows that you are likely to forget intended changes if they are not noted on the plan.

3.5. Preparation of the lesson plan

For your own initial training plans, it is advisable to follow the basic methodological rhythm of the phases "introduction", "development", "securing results" and "reflection" (see Fig. 2). These four phases should be interlinked in a meaningful way.

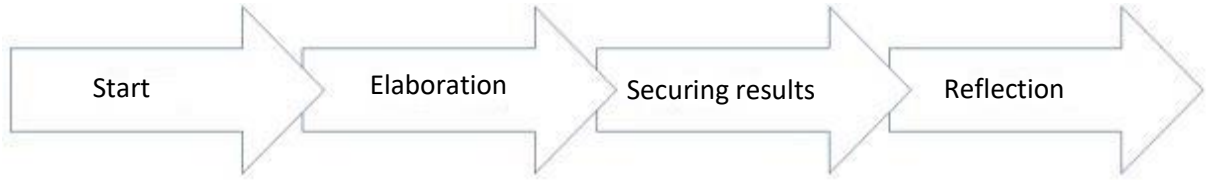

Figure 2: Basic rhythm of training

The purpose of the start is to open up the topic for the participants and to arouse their interest in the topic. The goal of this phase is for participants to recognize the need to address the issue or hypothesis.

In the elaboration phase, the participants should deal with the answer to the question or the clarification of the hypothesis.

After the development phase, the question or hypothesis raised at the beginning is taken up again and the new findings are secured. In this respect, the question raised in the introductory phase forms the common thread of the training.

The reflection phase is at the end of a training course or a training sequence. Its purpose is to enable participants to become aware of their past action and learning processes, to reflect on any difficulties they may have encountered and to consider ways of improving them. In this way, courses of action can be improved and successful patterns of action can be consolidated. (cf. Meyer 2007, p. 70 f.)

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4. Teaching methods

Trainers face a transition from a traditional pedagogical to a learner-centred approach rooted in learning outcomes, in which students are the drivers of their own learning process, while teachers / trainers take on the role of facilitators. We assume that if teachers understand their students' learning styles and the types of intelligence they can help their students to make the learning process more interesting and effective for them. All aspects raised will need to apply for the Additive Manufacturing Design Technician.

Objectives

- ❑ Teachers to use the most effective and efficient teaching methods to engage students;
- ❑ Enable active involvement;
- ❑ Enable critical discussions;
- ❑ Facilitate the knowledge development based on previous experience;
- ❑ Give value to differences. Consider fundamental differences in individuals' characteristics;
- ❑ Understand the differences in their students' learning styles;
- ❑ Identify the student's strengths in different fields of intelligence;
- ❑ Make students to explore, feel comfortable and develop self-confidence towards the contents.

4.1. Learner-centred didactics

The learner-centered approach aims at the development of learners' skills considering their personal characteristics, difficulties and achievements. Two fundamental aspects to be taken into account:

- ❑ Multiple intelligences;
- ❑ Learning styles.

Multiple intelligences

According to the theory of multiple intelligences (MI) there are eight "intelligences" in humans:

1. Bodily-kinesthetic: control of one's bodily / physical movements and ability to skillfully handle objects;
2. Interpersonal: interactions with others, including recognizing and understanding the moods, feelings and motivation of others;
3. Intrapersonal: introspective and self-reflective skills;
4. Logical-mathematical: dealing with logic, abstractions, reasoning, numbers and critical thinking;
5. Musical: rhythmic and harmonic sensitivity to sounds, rhythms, tones and musical rhythm;
6. Naturalistic: feeding information about one's natural environment;
7. Verbal-linguistic: show a structure with words and languages, including the ability to analyze information;
8. Visuo-spatial: deals with spatial judgment and the ability to visualize spatial objects and dimensions.

Learning styles

Learning styles refers to assuming that each student learns differently. VARK is an acronym that refers to four types of learning styles: visual, auditory, reading / writing preference and kinesthetic. Learning styles fall into four categories:

- Visual learners;
- Auditory learners;
- Reading/writing learners;
- Kinesthetic learners.

Challenges in shifting towards a complete leaner-centred didactics

- Knowing your strengths and weaknesses can be helpful;
- Although there are numerous types of intelligences, we must be careful not to confuse them with interests that can significantly overlap if not properly valued;
- Understand the best way to match assessments with students' learning styles;
- Trainers may be not comfortable incorporating a system that does not come with prescribed assessments and measurable results.

4.2. Collaborative learning

Collaborative learning consists in enhancing learning by engaging learners into working together in groups to share their ideas and points of view to solve a problem and/or to learn new concepts.

Benefits

- Exploit the group's strengths to address its learning needs;
- Better time management;
- Divide a large project into smaller tasks;
- Cooperate, resolve conflicts and reach a consensus.

Procedure

- Define a purpose: what collaboration skills must be acquired by learners?
- It is important learners work together by dividing their work for equal thinking, ensuring all ideas and suggestions towards a solution are taken in consideration;
- It is important that teachers/trainers are aware of the interactions between learners of the same group. This will allow them to improve the group dynamic.

4.3. Problem Based learning

Problem based application can be seen as making the learners to find a solution for a specific problem related to the subject matter at hand and to real world problems.

Basic principles

- Integrated learning (learners building thinking through direct experience);
- Contextual learning (benefits of learning from things that happen in learners' lives);

- ❑ Constructivism learning (connected with learning by doing);
- ❑ Active learning (learners actively involved in the learning process by doing and evaluating);
- ❑ Learning interesting (involve leaners in the determination of the problems).

Benefits

- ❑ Allow learners to apply the knowledge they already have to solve the problem;
- ❑ Provide learners the opportunity to think about concepts and solve real problems;
- ❑ Improve learners' motivation to learn and capacity to work with others in a working group.

Procedure

- ❑ Submission of a problem by the trainer, allowing learners to think of different ways to solve it;
- ❑ Analysis of the problem by learners, based on their previous knowledge about the subject as starting point for further investigating its issues;
- ❑ After this analysis, the next phase is that learners break down problems into components in a "brainstorming" session, allowing them to propose possible solutions;
- ❑ Development of a plan to obtain the information needed to solve the problem;
- ❑ Concluded the previous phase, learners must then report and present their results, in a discussion held in the presence of other learners;
- ❑ Finally, the development of material by teachers/trainers based on these results to be further studied by learners.

4.4. Critical thinking

Definition

Promote learners' ability to conceptualize, apply, analyze, synthesize and evaluate information, reaching their own conclusions. No correct answer is requested; the important is to make learners think about a given problem in a critical way, based on their own experiences.

Procedure

Teachers/trainers provide an information to learners and ask them to think about it in a critical way, through the following questions:

- ❑ Who said it?
- ❑ What was said?
- ❑ When was it said?
- ❑ Why was it said?
- ❑ How was it said?

5. Evaluation Teaching

Learning is a complex process. Its outcome – what students learn – is the result of multiple factors of individual and contextual nature. Among those is bound to be, of course, the quality of teaching, measured in terms of the efficacy of the teaching methods applied and the level of awareness of trainees' individual characteristics – such as *intelligence type*, *learning style* or *previous knowledge* – in the choice of the methods employed.

Learning is also the goal of teaching. So, it is critical that the result of the teaching method in place is checked also by means of the assessment of how much (how well) the students learnt, so that the method employed can be adjusted as needed, depending on the resources available, the trainer's abilities and the group of trainees in place.

So, the evaluation of the ***quality and effectiveness of teaching*** (which ***teaching*** shall stand for henceforth) needs to consider both the teaching style, method or resources and tools used, as well as the assessment of the knowledge gained by the trainees and the reasons thereof. In other words, evaluating teaching should entail both the evaluation of the teaching practice and its results, i.e., the degree of learning achieved.

On the other hand, evaluating teaching is a means of improving the quality of teaching itself. Seen and approached as reflective practice that focuses on a whole course or only specific parts of the learning programme, it helps revealing blind spots and enhances the trainer´s capacity to adjust contents and methods to the best outcome possible, i.e., what students learn and what new skills the new knowledge allows them to develop.

Lastly, a prerequisite to improving teaching is to have an **effective way to evaluate it**. In this sense, an effective and successful evaluation is one that generates outcomes that are valid, reliable, reproducible and which indicate directions and action for improvement. Given that the evaluation of teaching entails both the evaluation of acquired knowledge as well as the evaluation of the teaching methods, approach, or tools, one could ask where to start from. Having in mind that the way someone learns is highly dependent on one´s inherent characteristics, social and economic background, as well as pre-existent knowledge, the most effective way is to start by evaluating the learning profile and related aspects, concerning the specific group pf trainees in presence, in order to set the pace for the chosen teaching method, which can then be evaluated. In other words, as far as evaluating teaching is concerned, it is best practice to begin the evaluation process by the learning part, before we look into the effectiveness of the teaching method employed.

5.1. Evaluating learning

As stated already, learning is a complex process. The way we learn is deeply rooted in our own personal context and beliefs, as well as our previous knowledge and perception of the world. What we learn is a function of our existing ideas and perceptions of reality. People need to construct their own meaning regardless of how clearly teachers or books tell them things. If the new material conflicts with earlier misconceptions or firmly held assumptions, the students may ignore or distort the new information so that it fits into their old framework of understanding.

As for previous knowledge, learning is a cumulative process. Each new piece of information is added to what students already know (or believe) about the topic at hand. In terms of factual knowledge, if students have a solid foundation, the new pieces fit together more easily. However, if the students' preparation is spotty or incomplete, they may find it harder to grasp the new material.

So, setting the **evaluation of learning as the starting point** of our learning and teaching evaluation process., we should keep in mind that evaluating learning should be twofold: besides the assessment of previous knowledge on the subjects being taught, the trainer should preferably also have a measure of the main types of intelligence and learning styles of his/her trainees, in order to address necessary concepts and information in a way that enables trainees to learn in an effective and pleasurable way.

5.1.1. Assessing previous knowledge

Assessing previous knowledge should consider both:

a) a diagnostic evaluation at the beginning of the training and
b) regular formative assessment of acquired knowledge throughout the course or in-between modules.

Diagnostic evaluation methods

There are several ways to assess what students know on a certain subject or theme at the beginning of the training. The simplest way of diagnostic assessment is to ask the trainees questions relating to the subject of the course or the module. These can be open-end questions - such as "*what do you know about process X?*", "*why is Y important*?" or "*how do we know that*?" -, or closed-end ones, which have only one possible correct answer. If student answers are recorded, the same questions can be posed again at the end of the topic or term to evaluate students' progress.

A more comprehensive way to evaluate trainees' prior knowledge is to take a small diagnostic test, addressing key concepts, facts and figures and which should preferably be anonymous.

Formative evaluation tools

Typically, when teachers want to assess students' learning, they tend first to think of giving tests or quizzes. However, there are alternatives to the standard test or quiz. More informal ways can be used to determine whether students are learning the material throughout the term. Suggested alternatives could include:

i. Asking questions during class;
ii. Asking students for their questions, instead of inquiring if anyone has any questions;
iii. Giving frequent, short, in-class assignments or quizzes. A good idea on this respect is to encourage trainees to compare answers with their neighbours, especially for the case of open-ended questions.
iv. Asking trainees to state what they found more surprising or difficult to understand, or else, what was already familiar to them. These statements should preferably be handed in writing, in order to keep record of all feedback to reflect upon.

5.1.2. Summative assessment of knowledge

While formative assessment is the evaluation of learning as it takes place (assessment for learning), **summative assessment** is the practice of evaluating what trainees have learned at the end of a given period of time (assessment of learning), typically against standardized criteria often measured with a grade or percentage, depending on the subject. Results obtained in the summative assessment of students are already, as mentioned, a first measure of the quality and effectiveness of the teaching method employed, depending on the average grade obtained for a given class.

Examples of summative assessments may include written assessments, performance assessments, entailing the students showcasing their abilities and knowledge by means of an activity or specific tasks, standardized assessments (exams), evaluated against existing criteria, or oral assessments, where trainees deliver an oral piece, such as a speech or presentation.

On the other hand, summative assessment provides an essential benchmark to check the progress of trainees as well as VET centres. Because of this, summative assessment can also be used to improve the curriculum or teaching methods and resources, should results reveal a generalized poor performance of the majority of the trainees.

5.2. Evaluating teaching

In addition to the information obtained from the summative assessment results, in terms of how effective the teacher was in conveying the course contents and in the overall achievement of the learning outcomes for a given class, there are several methods for the evaluation of the teaching and/or the course or module being taught. Complimentary to the feedback from the summative evaluation of students, feedback from the *teaching* and *the course* evaluation process provides a means to identify aspects of a particular teaching method, or design of a specific module or course that need attention.

Teaching evaluation is vital, as it speaks to reflective practice that specifically uses evaluation as a means to focus on the course or specific competence units to teach them in a meaningful way to develop and enhance one's own teaching, but also student learning. Through the teaching and course evaluation process, one is afforded the opportunity to reflect on feedback, which allows one to identify and improve aspects of teaching a particular module or course that need attention.

The most important consideration in teaching and courses evaluation is the use of multiple sources of data. Data obtained from each source of observation or feedback, when considered together, provides a balanced picture of the course or module as well as of the effectiveness of the teaching style. By thinking carefully about the purpose of evaluation, and by crafting multiple methods of evaluation that suit those purposes, it is possible to devise evaluation systems that are reliable, valid, and fair.

As good practice in teaching evaluation, the first aspect that should be considered is **setting the boundary of what is to be evaluated**. The entire course, a specific module, the teaching skill of the trainer, students' previous knowledge on a given subject, or a combination of these. After what is to be evaluated is clearly defined, then the **focus of the evaluation exercise** should be defined. As an example, if I set the boundaries of my evaluation problem to be a specific module, then I need to decide exactly what I want / need to assess; - is it the way the theoretical content is structured and presented, is it the tools I am using to teach it, or the assessment methods, to name a few aspects I may choose or need to focus on. **Fehler! Verweisquelle konnte nicht gefunden werden.** illustrates this very important aspect – the focus of evaluation – by listing some examples of questions to ask in order to determine exactly what is to be evaluated. Focus definition then provides useful information for setting up the most adequate method of evaluation or data gathering.

Table 1: useful questions regarding defining the focus of a given evaluation

Focus area for evaluation	Questions you could ask
The learning experience	Are the aims of the session and the learning outcomes clearly stated at the outset and met through the learning and teaching activities?

Focus area for evaluation	Questions you could ask
	Are learners motivated and actively engaged in learning? Are they attentive and participating when required?
	Is the content presented in an effective and engaging way, employing a variety of methods?
Assessment of learning	Is the assessment method clear, transparent and valid?
	Are the assessment criteria accessible and at the correct NQF Level?
	Is the quality of feedback appropriate and linked to improving learner performance?
Curriculum	Is the curriculum challenging enough, holding learners' interest?
	Does the curriculum develop skills knowledge and experience relevant to the programme and individual professional development?
	Do learners take advantage of support and resources?

5.2.1. Teaching evaluation methods

Once the purpose of evaluation and its focus have been determined, it is good practice then to apply the method of evaluation that best suits these criteria. There is always an advantage in using several methods of evaluation and correlating their outcomes.

Most common classes of evaluation (entailing data gathering) methods are **questionnaires**, **structured group interviews**, **self-evaluation** and **peer evaluation**.

Questionnaires

This common and familiar method of seeking feedback from learners and participants has the potential advantage of speed (in administration), anonymity (of response) and standardisation (for purposes of comparison between classes). The shortcomings can include poor response rate and validity of the outcomes, if the questionnaire is not designed correctly (in terms of purpose and focus), and if questionnaires are over-used (effect of "questionnaire-fatigue").

Important points to consider include (a) the type of questions (open or closed) to use, (b) the scale used to measure the close-end questions, (c) the length of the questionnaire or (d) when to use it. Regarding this latter aspect, for instance, the decision on when to perform the questionnaire depends on its main purpose. For example, evaluation at the end of a module may provide a more complete picture but leaves little room for improvement for that edition of the course. Evaluation part-way through the module may miss important information but, on the other hand, allows time for adjustments.

Structured group interview (nominal group technique)

This is a meeting with learners or participants where they are asked to give their views about a programme, course or class. The meeting must be planned and structured carefully to generate constructive debate, and so that trainees feel free to express their views without personal risk. Typically, learners are asked to work in small groups to reflect upon positive and negative features of the educational provision (e.g. programme, course or module), its delivery, and their own performance and experience. A spokesperson from each group

is asked to relay the considered views of the group to the meeting. The role of the member of staff leading the meeting is to compile a summary of such views, to validate them at the meeting, and, later, to produce a short report of the main outcomes. Learners who take part should be provided with a copy of the written report.

The structured group interview allows learners to have greater freedom of expression than in a questionnaire, and more opportunity to make constructive suggestions for improvement. It typically requires a meeting of about an hour, but the processing is done during that hour and the time needed for producing a report is short.

Self-evaluation

A simple but effective self-evaluation method is for the trainer to undertake the same form of evaluation applied to the learners, i.e. to complete the same questionnaire, or to conduct a self-evaluation using the same format of a structured group interview. The degree of agreement between the trainer´s responses and the outcomes of the learners' evaluation is a good indicator of the trainer´s awareness of learner perceptions. Items of disagreement indicate a need to address those aspects referred to by the students and hitherto ignored or overlooked by the trainer.

Peer evaluation

While observation by colleagues should be approached with caution, if results are to be used for summative evaluation, peer observation is an excellent method for improving teaching. A colleague, focusing on the process that is taking place, adds a dimension of evaluation that may escape the trainer and the trainees, who are generally too busy with the business of teaching and learning to observe the process itself. Furthermore, colleagues who have expertise in the discipline being taught, and training in what to observe, can provide important feedback information through classroom visits and review of course materials.

It is especially effective when done reciprocally as part of a teaching circle or mentoring relationship and reflected upon in a teaching portfolio. In fact, it could be argued that observing teaching improves the teaching of the observer as much as the teaching of the observee, especially if the observer reflects on what he/she has observed in the classroom.

The evaluation process is enhanced when, prior to classroom visits, colleagues review the curriculum and course-related materials and discuss teaching goals. It is good practice for peer evaluation to be a planned and structured process, involving the separate stages of

1. **Briefing**, to set context and identify aims and learning outcomes for the process that is to be observed.
2. **Observation** in which the observer records what happens in the class(es). A checklist of key features to look for, previously agreed upon during the briefing, is used by the observer.
3. **A period of analysis** in which the observer analyses what he/she has seen in relation to the terms of the briefing meeting and other matters arising out of the observation.
4. **A post-observation meeting,** to give feedback on the observation and to compare the perceptions of the observer and the observee. The observer and the observee will then discuss strategies for development/management of problems.

5.2.2. Final remarks

Teaching evaluation is paramount to achieving good quality teaching, one that is effective, in terms of getting students to achieve the learning outcomes expected, and one that takes into account interests and particular intelligence types and learning styles, in order to enhance trainees´ motivation and self-esteem.

For this reason, research suggests that effective teachers all have in common two important characteristics:

- They try to anticipate the topics and concepts that will be difficult for their students and to develop teaching strategies that present these topics in ways their students will best understand. These teachers make a special point of becoming familiar with their students' preparation, knowledge, and abilities, and adjust their teaching to maximize the class's learning.
- Through frequent assessment and feedback, they regularly assess what they do in the classroom and whether their students are really learning.

A prerequisite to improve teaching is thus to have an effective way to evaluate it. That involves collecting data from multiple sources – ratings from students, peers and administrators, self-ratings, and learning outcomes – that reflect on every aspect of teaching, including **course design**, **classroom instruction**, **assessment of learning outcomes**, **advising** and **mentoring.**

Upon defining what is to be evaluated and what the evaluation process will focus specifically on, the most adequate method or methods can then be chosen. If the evaluation process is well conducted, generating valid outcomes and directions for change, adjustments can then be made. Applying this methodology recursively, taking care to use data from multiple sources and feedback obtained by means of different (and complementary) evaluation methods, in order to obtain a completer and more overall picture, is bound to lead to continuous improvement in teaching and, hence, better results in learning.

6. Case Studies

DESTINE project partners developed 3 case studies per new developed competence unit (9 in total), addressing the skills to be applied in this competence unit. This case studies were prepared using an excel template that enables two features. The complete document can be used as an example or case study to be presented during the lectures with the described problem, the task and the solution. Another way is to use this as practical task in an assessment of for self-learning when only presenting the task and the trainee has to think on the solution him- or herself. In this short version of the guide, one case study for the CU Design for DED processes is presented.

6.1. Case Study Impeller: Planning & Preparation

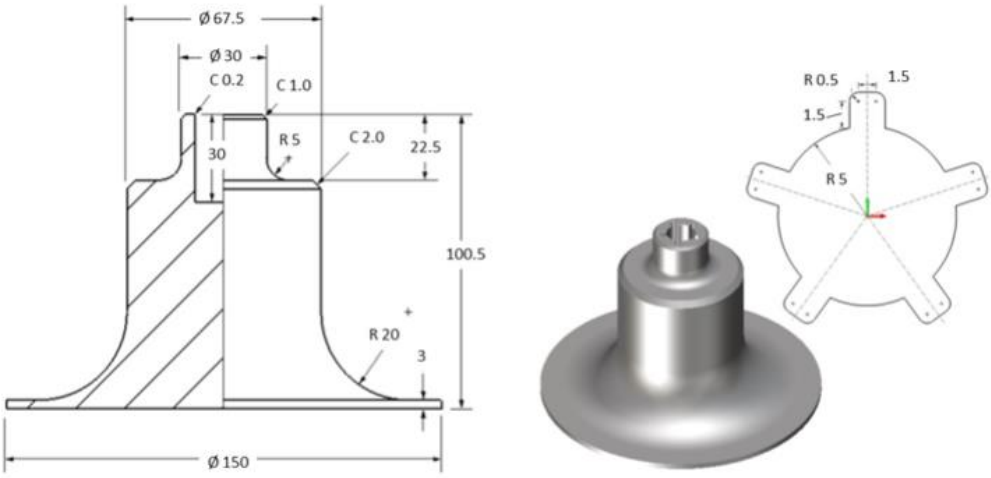
Case Study / Practical Exercise: Planning & Preparation Unit of LOs/ CU: *Design for DED processes*
1. Name of Case Study / Practical Exercise: IMPELLER
2. Identify the verifiable goal in a teaching perspective:
The trainee designs the specific component taking into account the provided design and the requirements of DED process in additive manufacturing and the need of post-processing
3. Identify which are the assessment criteria that will be considered to determine the performance of the trainee:
The trainee should be capable to: *Adapt the design part accordingly to the specifications of the DED process* *Respect dimensions* *Provide room for post-processing*
4. Estimate the duration of the usage of CAD for the development of the design in hours: 3 h
5. Indicate the overall time of the exercise (including the use of CAD and the explanation supporting how the design was performed): 4 h
6. When applicable, indicate the minimum and maximum number of trainees per group: 1
7. Indicate which materials, software and equipment are necessary for supporting the delivery of the practical exercise or case study. The supporting materials have to be attached. (Examples: machine specifications, feedstock specifications, drawings, standards, software....):
Machine specifications, feedstock specifications; Supporting materials attached: 2D drawings, standards; Software: Tinkercad

8. When applicable, describe where the exercise /case study is performed and which conditions may influence the performance. Example: Classroom with adequate light, machine shop floor etc.
Room with adequate light and computer with CAD software

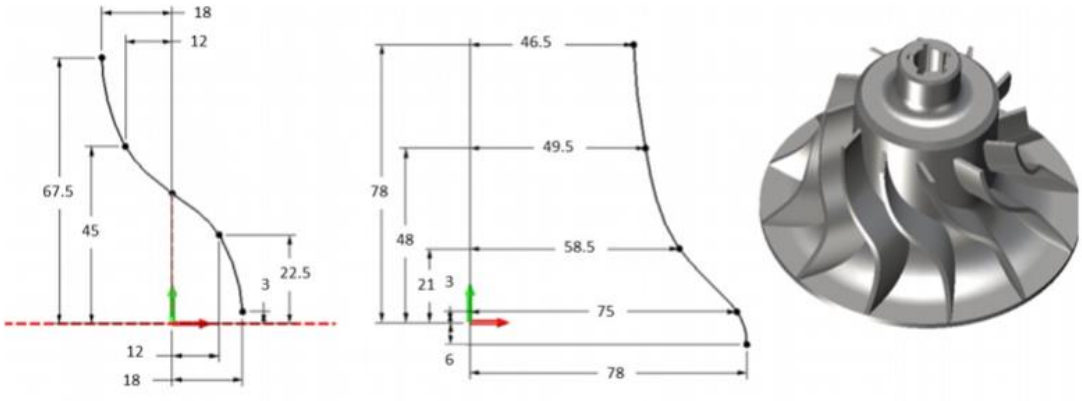
6.2. Case Study Impeller: Case Study or Practical Exercise

Case Study / Practical Exercise: Task Unit of LOs/ CU: Design for DED processes
Name of Case Study / Practical Exercise: IMPELLER
Verifiable Goal: The trainee designs the specified component taking into account the task and the requirements of the additive manufacturing process
Overall time for the exercise (including the use of CAD and the explanation supporting how the design was performed): 4 h
Assessment Criteria:
SUMMARY (detailed presentation / description with task of the case study / practical exercise)
Effective reparation and remanufacturing of mechanical components like impellers can be achieved by DED processes. *The picture reflects the design of an impeller used within a centrifugal pump. There is a need of substitution of the original impeller for a new one due to a breakage.* *The goal of this exercise is to re-design the impeller with its specific features like holes, curves and angles from the body (part 1).* *The task also involves designing new blades that must be affordable with a DED process. The only condition is to maintain the total number of blades (12) and their thickness (2.25 mm).*
INSTRUCTIONS (steps and tasks necessary to conduct the case study)
Starting data:
1. Read the technical drawing of the corresponding impeller.
2. Draw piece according to given dimensions
The impeller will be made of metal (Fe19Ni5Ti steel) using DED-LB process
RESOURCES NEEDED (identification, specification and attachment)
Technical drawing; Room with adequate light (natural and artificial); Computer with the corresponding software; Mouse; Adjustable chair; Electrical extensions; Scale ruler

Step 1: Design of the base with the corresponding hole



Step 2: Original design impeller blade.
(Number is 12; Thickness is 2.25 mm)



6.3. Case Study Impeller: Solution & Reasoning

Case Study / Practical Exercise: Solution

Unit of LOs/ CU: Design for DED processes

Name of Case Study / Practical Exercise: IMPELLER

SOLUTION & REASONING

The impeller design can be observed as the combination of two different parts: the body and the blades. The body means the consideration of the hole with the corresponding notches. The geometry of the blades involves different possible solutions according to each design technician.