

Project title:

Creating know**L**edge and skill**L**s in **A**dditive **M**anufacturing



CLLAIM

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Introduction

The main aim of Creating KnowLedge and SkillLs in Additive Manufacturing (CLLAIM), set to address the Manufacturing & Engineering sector, is to develop a brand-new European sector-oriented qualification system and body in Additive Manufacturing (AM) through the exchange among EU partners about an innovative training curriculum. The glossary describes all special definitions used in the project.

1. General

<i>3D printer</i>	Machine used for 3D printing
<i>3D printing</i>	Manufacturing of components and objects by applying a material with a print head, nozzle or other printing technology. The term is often used in a non-technical context as a synonym for additive manufacturing whereas to date, 3D printing has been associated in particular with machines which are low-priced and/or of low overall performance.
<i>Additive Manufacturing (AM)</i>	Process of joining materials to fabricate components from 3D model data, layer by layer. Opposed to subtractive and forming manufacturing methods
<i>AM system/AM equipment</i>	Machine and additional equipment used for AM
<i>AM machine</i>	Section of the AM system, including hardware and machine control software, required commissioning software, and peripheral accessories necessary to complete a build cycle for the production of components
<i>AM machine user</i>	Person or group using an AM machine
<i>AM process</i>	Process of building parts by means of additive manufacturing
<i>AM system user</i>	Person or group using an entire AM system or component of an AM system
<i>APS (Additive manufacturing specification)</i>	Document that has been qualified and provides the required variables of the additive manufacturing process to ensure repeatability during production
<i>Equipment control</i>	Preparation, quality management, maintenance, programming and usage of equipment needed for AM processes
<i>Filament</i>	Building material which is characterised by extreme length in relation to its uniform cross section.
<i>Material control</i>	Preparing, handling, quality management and recycling of materials used in AM processes

<i>Material supplier</i>	Provider of materials / feedstock for the production in AM systems
<i>Multi-level process</i>	AM-process in which parts are built in two or more steps where the first step typically supplies the geometric form and the next steps supply the basic properties and features of the part
<i>pAPS (preliminary additive manufacturing procedure specification)</i>	Document containing the required variables of the additive manufacturing procedure which has to be qualified
<i>Post build inspection</i>	Quality check, tests, measurements and reports about quality deviations on the finished parts
<i>Process chain</i>	Sequence of operations necessary to achieve the intended functionality and characteristics of the component
<i>Production run</i>	All components that are produced in one single building process or in a series of building processes with the same materials and process parameters.
<i>Single-level process</i>	AM process in which parts are built in one single step. This single step supplies the geometric form as well as all the basic material properties and features of the part.

2. Processes

Binder jetting (BJ)

AM process, in which a liquid binder is specifically deposited on powder materials for creating a connection. Every layer of powder is selectively provided with the binding agent to create bonding to the layers below and form the geometric form of the component. The process works with metals, plastics and ceramics.

Directed energy deposition (DED)

AM process, in which a focused heat energy is used to fuse material during deposition by melting. Thermal energy is provided by means of lasers, electron beam, plasma arc, electric current or kinetic energy. The process works only with metals. The material can be supplied as powder or wire.

Material extrusion (MEX)

AM process, in which materials can be specifically dosed with a nozzle or orifice. The process works with metals, plastics and composites. Depending on the material, heating must be applied to form a proper bonding. The material can be supplied as granulate, filament or paste.

Material jetting (MJ)

AM process, in which drops of the feedstock can be specifically deposited. Typically, the drops are nano particles of the used material mixed with a special suspension. After deposition, the current layer is heated by means of heat or UV radiation to evaporate the suspension. The process works with metals, plastics and ceramics.

Powder bed fusion (PBF)

AM process, in which thermal energy melts or sinters targeted areas of a powder bed. Thermal energy is provided by lasers or electron beams. The process works with metals, plastics and composites. Some powder bed processes with plastics use fusing and detailing agents which are heated by means of infrared radiation to fuse the powder.

Sheet lamination (SL)

AM process, in which material layers are joined to form a component. The layers are joined by means of adhesives. During the process, every layer is cut into the desired geometric form by a laser or a cutting tool. The process works

with metals, plastics, ceramics, paper and other materials.

*Vat photopolymerization
(VAT)*

AM process, in which a liquid photopolymer in a vat is cured by light-activated polymerization. The activation is realized by lasers or ultra violet radiation. The process works with metals, plastics and composites.

3. Processing: General

<i>Build chamber</i>	Enclosed space within the AM system, in which the components are manufactured. The size of the build chamber determines the maximum length, width and height of the built component
<i>Build cycle</i>	Single process cycle in which one or more components are built up in layers in the process chamber of the AM system
<i>Build plane</i>	Area where material is added, usually on the last deposited layer, which becomes the basis for the next to be formed layer
<i>Build platform</i>	Base that provides a surface on which the manufacturing of the component(s) is started and supported during the building process. The size of the build platform determines the maximum length and width of the built component
<i>Build space</i>	Place where it is possible to make components, typically inside the build chamber and/or on a build platform
<i>Build volume</i>	Total usable volume available in the machine for building components. The size of the build volume determines the maximum size of the built component
<i>Extruder head/extrusion head</i>	Assembly comprising the feed mechanism for the building material and extrusion. A common design of an extruder head includes a motorized feed mechanism to push filaments through the extrusion head. The head often includes a heating element
<i>Extrusion nozzle</i>	Assembly with an opening through which the building material is extruded
<i>Feed region</i>	Place in the machine where feedstock material is stored and from which a quantity of the feedstock material is constantly or repeatedly transported during the build cycle
<i>Layer</i>	Deposited material for the production of a surface. Additively manufactured components are usually built “layer by layer” where one

	layer is finished before the next layer is built upon and bonded to the layers below
<i>Overflow region</i>	Place(s) in the machine where excess powder is stored during a build cycle
<i>Process parameters</i>	Set of operating parameters and system settings used during a build cycle
<i>Support/support construction</i>	A structure which is not part of the geometry of the component and which is manufactured to serve as a base and anchorage for the component during the construction process, support is usually removed from the component after finishing the building process.
<i>System set-up</i>	Configuration of the AM system for a build cycle

4. Processing: Data

<i>3D scanning/3D digitizing</i>	A method of obtaining the shape and size of an object as a 3-dimensional representation by detecting the X, Y and Z coordinates on the surface of the object and converting the accumulated points into digital data by software
<i>AMF - AM File Format</i>	Additive manufacturing file (AMF) format for communication of AM model data including a description of the 3D surface geometry with support for color, materials, lattice, structures, constellations and metadata
<i>IGES - Initial Graphics Exchange Specification</i>	platform-neutral CAD data exchange format designed to exchange product geometry and geometry tag data
<i>Resolution</i>	Dimensions of the smallest component feature that can be built in a controllable manner. In a layered construction process the resolution in the Z-direction is usually identical to the layer thickness.
<i>STEP - Standard for the Exchange of Product model data</i>	Standard for the exchange of product model data
<i>STL - Standard Triangulation Language</i>	Model data file format that describes the surface geometry of an object as a mosaic of triangles used to communicate 3D geometries to machines to build physical components
<i>Surface model</i>	mathematical or digital representation of an object as a set of planar or curved surfaces, or both, which may or may not represent a closed volume

5. Processing: Materials

<i>Batch</i>	Specified quantity of the building material with uniform properties and composition. A batch of material may be used in one or more production cycles with different process parameters. For some materials like powders a batch may consist of new material, used material or a mixture of new and used material.
<i>Curing</i>	Chemical process that leads to the final properties of a surface or other material
<i>Feedstock</i>	Raw material supplied for the AM process
<i>Fusion</i>	Process of uniting two or more units of material into a single unit of material
<i>Laser sintering/Laser melting</i>	Powder bed based melting process for manufacturing articles out of powder materials with one or more lasers for targeted fusing or melting of the particles at the surface, layer by layer, in a closed build chamber
<i>Powder cake</i>	Weakly bonded powder that surrounds the manufactured component(s) at the end of a build cycle
<i>Post-processing</i>	Process steps taken after completion of an AM build cycle to achieve the desired end product properties or shape
<i>Powder batch</i>	Powder used as feedstock, which could be used powder, virgin powder or a mixture of both
<i>Powder bed</i>	Construction area in an AM system, in which feedstock is deposited and fused selectively by a heat source or connected by an adhesive to build components
<i>Powder blend</i>	Amount of powder of thoroughly blended powder originating from one or more powder lots of the same nominal composition
<i>Powder lot</i>	Amount of powder produced under detectable, controlled conditions from a single powder manufacturing process run
<i>Used powder</i>	Powder delivered to an AM machine as

feedstock during at least one previous build cycle

Virgin powder

Unused powder from a single powder batch

6. Applications

<i>Component</i>	Fused material that forms a functional element that may constitute an entire or a segment of a designated product
<i>Prototype</i>	Physical representation of an entire product or segment thereof that may be used with limitations for analysis, design and evaluation
<i>Rapid prototyping</i>	Application of AM, which is intended to reduce the time required to produce prototypes
<i>Rapid tooling</i>	Application of AM, which is intended for the production of tools or tool components with a shorter lead time compared to conventional toolmaking
<i>Tooling prototype</i>	Molds, dies and other devices used for prototype purposes; sometimes called bridging tools or soft tooling

7. Properties

<i>Accuracy</i>	Closeness of the match between an individual result and an accepted reference value
<i>As-built</i>	Refers to the condition of components produced by AM prior to post-processing, except, if necessary, the removal from a build platform and of supports and/or unprocessed feedstock
<i>As-designed</i>	Condition of the component in its digitized form, typically as 3D data
<i>Fully dense</i>	Condition in which the material of the manufactured component is free of significant pores
<i>Near net shape</i>	Condition in which the components require little post-processing to meet dimensional tolerances
<i>Porosity</i>	Presence of small pores in a component, which makes it less than fully dense
<i>Reference part</i>	Part with similar properties to the components to be built but with different proportions for easier testing and describing
<i>Repeatability</i>	Degree of agreement of two or more measurements of the same property, with the same equipment and in the same environment
<i>Spreadability</i>	Property of the building material to be spread out in layers which correspond to the build process' requirements

8. Educational terms

<i>Accreditation</i>	Formal testification that a person, a business or any institution is competent to fulfill specifically defined tasks
<i>Appeal</i>	Request by applicant, candidate or certified person for reconsideration of any decisions made by the certification body related to his/her desired certification status
<i>Assessment</i>	Process that evaluates a person's fulfillment of the requirements of the certification scheme
<i>Assessment of learning outcomes</i>	Process of finding out which knowledge, skills and competencies the learner has acquired so far to define a proper curriculum for the learner to teach him the needed skills, knowledge and competencies. The assessment normally follows predefined criteria and seeks information such as the learning expectations of the learner or already obtained and practiced skills
<i>Basic skills</i>	Skills needed on a sufficient level to take part in modern society such as speaking, listening, reading, writing, mathematics
<i>Candidate</i>	Applicant who has fulfilled specified prerequisites and has been admitted to the certification process
<i>Certificate</i>	Document issued by a certification body under the provisions of this International Standard, indicating that the named person has fulfilled certain certification requirements
<i>Certification of learning outcomes</i>	Formal testification by a competent body through a certificate, diploma or title that proves successful assessment and validation of certain learning outcomes.
<i>Certification Process</i>	Activities by which a certification body determines that a person fulfills certification requirements including application, assessment, decision on certification, recertification and use of certificates.
<i>Certification requirements</i>	Set of specified requirements, including requirements of the scheme to be fulfilled in

	order to establish or maintain certification
<i>Certification scheme</i>	Competence and other requirements related to specific occupational or skilled categories of persons
<i>Competence</i>	The ability to apply sufficient knowledge, judgment, skills, or strength in specific work or personal situations
<i>Complaint</i>	Expression of dissatisfaction by any individual or organization to a certification body relating to the activities of that body or a certified person
<i>Course Materials</i>	Collection of different learning materials such as books, papers, worksheets to provide all relevant content for the learner to acquire the aimed skills, knowledge and competencies
<i>Cross-sector competences</i>	Competencies that can be applied in several economic fields
<i>Curriculum</i>	Pre-set inventory of activities to fulfill an educative action such as learning outcomes, training contents, suitable methods and needed materials. Also includes arrangements for training teachers
<i>Digital Competence</i>	Ability to proper use of information and communication technology such as computers or smart devices as well as to exchange information and participate in networks such as the internet
<i>Examination</i>	Mechanism that is part of the assessment which measures a candidate's competence by one or more means, such as written, oral, practical and observational, as defined in the certification scheme
<i>Examiner</i>	Competent person to conduct and score an examination, where the examination requires professional judgement
<i>Examining body</i>	Organization that has been appointed to verify compliance with the applicable standard
<i>Facilities and Equipment</i>	Needed machines, systems, plants, tools etc. to use for training purposes to provide practical exercise for the learner. Also including facilities

and equipment for health and safety requirements, appropriate classrooms and visual aids of good quality

<i>Fairness</i>	Equal opportunity for success provided to each candidate in the certification process
<i>Formal learning</i>	Process of learning delivered and supported by trained teachers within a structured environment such as a school or a university
<i>Green skills</i>	Skills needed to actively take part in and develop a society that aims to reduce negative human impact on the environment
<i>ICT (information and communication technology) skills</i>	Skills needed to use information and communication technology efficiently
<i>Impartiality</i>	Presence of objectivity
<i>Informal learning</i>	Mostly unintentional learning process in daily activities that is not organized or structured regarding time, aims or supports.
<i>Interested party</i>	Individual, group or organization affected by the performance of a certified person or the certification body
<i>Invigilator</i>	Person authorized by the certification body who administers or supervises an examination but does not evaluate the competencies of the candidate
<i>Know-how</i>	Knowledge, expertise and experience to manage practical situations
<i>Language</i>	The method of human communication, either spoken or written, consisting of the use of words in a structured and conventional way
<i>Learning</i>	Process of acquiring new knowledge, skills or competencies as well as modifying them
<i>Learning attainment</i>	See learning outcome
<i>Learning-by-doing</i>	Learning process through repeated practice of certain tasks with or without instructions prior or during the practice
<i>Learning outcome</i>	Statement of what a learner knows,

	understands and is able to do (skills and competencies) after completing a defined learning process
<i>Lifelong learning</i>	All learning activities throughout life at any age to improve or acquire new knowledge, skills and competencies
<i>Location</i>	All needed places to carry out the learning activities needed for the learner to acquire new skills, competencies and knowledge as well as qualifications.
<i>Non-formal learning</i>	Intentional learning process in a more or less structured environment without a teacher, curriculum, accreditation or certification
<i>Personnel</i>	Internal or external individuals of the certification body carrying out activities for the certification body
<i>Qualification framework</i>	Set of criteria to determine and classify specified levels of learning outcomes
<i>Qualification Level</i>	Qualifications are grouped in different levels. Each level corresponds to a certain degree of difficulty of a particular qualification.
<i>Reliability</i>	Indicator of the extent to which examination scores are consistent across different examination times and locations, different examination forms and different examiners
<i>Scheme owner</i>	Organization responsible for developing and maintaining a certification scheme
<i>Sector-specific knowledge, skills and competences</i>	Knowledge, skills and competencies, that are relevant for more than one occupation, task or job within one specific sector.
<i>Skill needs</i>	The demand for certain skills, qualifications or competences on the labour market to fulfill certain jobs
<i>Skill mismatch</i>	The gap between a person's current skills and the demand of the labour market or the assigned job. It is distinguished between vertical mismatch and horizontal mismatch where vertical means the level of skills higher or lower than required and horizontal means

	the type of skill mismatches the current job.
<i>Skill shortage</i>	The number of people at the labour market that have the skills needed for a certain job does not match the demanded number of people for this job
<i>Surveillance</i>	Periodic monitoring, during the periods of certification, of a certified person's performance to ensure continued compliance with the certification scheme
<i>Team of Lecturers</i>	A team of lecturers or teachers to teach certain skills, competencies and knowledge and to support learners with their training
<i>Transferability of learning outcomes</i>	Possibility to apply gained knowledge, skills or competencies in a different or new task, field or environment
<i>Transversal competences</i>	Competencies that can be applied to a broad range of fields and situations
<i>Upskilling</i>	Follow-up training to improve, fortify or update knowledge, skills and competencies already acquired through previous training/learning. The upskilling training typically follows shortly after the initial training
<i>Work-based learning</i>	Process of acquiring knowledge, skills and competencies through practical expertise and reflection of certain assigned tasks in a vocational environment
<i>Validation of learning outcomes</i>	Process of proving that the learner has acquired defined learning outcomes and/or skills and competencies needed to fulfill a certain task
<i>Validity</i>	Evidence that the assessment measures what it is intended to measure, as defined by the certification scheme
<i>VET</i>	Vocational education and training (VET) aims to supply a person with knowledge, skills and competencies needed to qualify for a certain employment, occupation, job or need on the labour market

9. Project specific terms

ANB A legal organization authorized by the International Institute of Welding (IIW) to implement an international harmonized qualification system

ATB An authorized training body (ATB) is an organization that has been assessed and approved by an ANB in accordance with IIW rules for training organizations. By awarding ATB status, the ANB confirms that the ATB fulfils the requirements for delivering training in accordance with one or more IIW guidelines. It shall be an organization independent from the ANB or clearly separated from it

CU's Same as training module or training unit. A Competence Unit (CU) can be Cross-cutting or Functional:

a. Cross-cutting Competence Unit: a competence unit not directly linked with one job function since the knowledge and skills achieved will be mobilized across several job functions and activities;

Functional Competence Unit: a competence unit directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities

DED-Arc Operator Trained operator with specific competencies, knowledge and skills as well as responsibility and autonomy to operate AM machines using directed energy deposition and plasma arcs processes.

His or her main tasks are operating directed energy deposition machines (fitting, setting up, run, maintenance, repairing). He or she is able to remove built parts and prepare them for post-processing and to solve problems related to the machine and process.

Needed knowledge

- Additive Manufacturing processes

- DED-Arc process and manufacturing of DED-Arc parts
- Build file set-up, software and hardware needed for DED-Arc processes
- Verifying arc related parameters
- Positioning in DED-Arc machines
- Managing the feedstock-handling
- Post processing
- Maintenance of the system
- Quality assurance in DED-Arc
- Health and safety in DED-Arc processes

DED-LB Operator

Trained operator with specific competencies, knowledge and skills as well as responsibility and autonomy to operate AM machines using directed energy deposition and laser beam processes.

His or her main tasks are operating directed energy deposition machines (fitting, setting up, run, maintenance, repairing). He or she is able to remove built parts and prepare them for post-processing and to solve problems related to the machine and process.

Needed knowledge

- Additive Manufacturing processes
- DED-LB process and manufacturing of DED-LB parts
- Build file set-up, software and hardware needed for DED-LB processes
- Laser beam characterization
- Positioning in DED-LB machines
- Managing the feedstock-handling
- Post processing
- Maintenance of the system
- Quality assurance in DED-LB
- Health and safety in DED-LB processes

Designer

A person who plans the look or workings of something prior to it being made, by preparing drawings or plans regarding the process limitations

ECTS

European Credit Transfer and Accumulation System (ECTS) is an instrument used in the European Higher Education Area in European countries as well as Norway, Switzerland, Israel and other non-EU countries. It structures

university studies and improves transparency to weighting its components

ECVET

European Credit System for Vocational Education and Training (ECVET) is a system for accumulating and transferring credit points in vocational education and training. It can be used to document and certify learning outcomes that a person has achieved in vocational education and training across "system boundaries". Qualifications should not be described by the effort required to acquire them, but by the learning outcomes and competences achieved

Engineer

A person trained and skilled in the design, construction and use of engines or machines, or in any of various branches of engineering

EQF

European Qualification Framework (EQF) acts as a translation device to make national qualifications more readable across Europe, promoting workers' and learners' mobility between countries and facilitating their lifelong learning. The EQF aims to relate different countries' national qualifications systems to a common European reference framework. Individuals and employers will be able to use the EQF to better understand and compare the qualifications levels of different countries and different education and training systems

ESCO

ESCO is an initiative that supports Europe 2020 and Skills agenda for Europe. European Skills, Competences, Qualifications and Occupations (ESCO) is the European multilingual classification of Skills, Competences, Qualifications and Occupations. ESCO works like a dictionary, describing, identifying and classifying professional occupations, skills and qualifications relevant for the EU labour market and education and training. The ESCO taxonomy is constructed under these 3 pillars: occupations, skills/competences and qualifications

Inspector

A person whose job is to officially inspect something, for example, a factory or building, in order to check that everything is legal and in the correct condition

<i>Knowledge</i>	A list of knowledge topics to be addressed in a given Competence Unit
<i>Milestone</i>	Planned time schedules and data prescribed for making ready (acceptable) the given deliverables/results
<i>NQF</i>	National Qualification Framework (NQF) is a set of criteria which acts as an instrument to classify different specified levels of learning outcomes in a national qualifications subsystem. It aims to improve transparency of and access to qualification systems in a society as well as to the labour market
<i>Occupational standards</i>	Statements of work performance reflecting the ability to successfully complete the functions required in an occupation, as well as the application of knowledge, skills and understanding in an occupation. Occupational standards are defined in terms of activities performed by a person in a given occupation whereas education and training standards are developed from the activities defined in occupational standards, and they include learning outcomes and learning activities, which ensure that the necessary skills and knowledge are developed by a person to enable him or her to perform at an agreed level in an occupation
<i>Operator</i>	A person who operates equipment or a machine
<i>PBF-EB Operator</i>	<p>Trained operator with specific competencies, knowledge and skills as well as responsibility and autonomy to operate AM machines using powder-bed based electron beam processes.</p> <p>His or her main tasks are operating powder-bed based electron beam machines (fitting, setting up, run, maintenance, repairing). A PBF-EB Operator is able to remove built parts and prepare them for post-processing and to solve problems related to the machine and process.</p> <p>Needed knowledge</p> <ul style="list-style-type: none"> • Additive Manufacturing processes • PBF-EB process and manufacturing of

PBF-EB parts

- Build file set-up, software and hardware needed for PBF-EB processes
- Powder handling
- Electron beam characterization
- Post processing
- Maintenance of the system
- Quality assurance in PBF-EB
- Health and safety in PBF-EB processes

PBF-LB Operator

Trained operator with specific competencies, knowledge and skills as well as responsibility and autonomy to operate AM machines using powder-bed based laser beam processes.

His or her main tasks are operating powder-bed based laser beam machines (fitting, setting up, run, maintenance, repairing). A PBF-LB Operator is able to remove built parts and prepare them for post-processing and to solve problems related to the machine and process.

Needed knowledge

- Additive Manufacturing processes
- PBF-LB process and manufacturing of PBF-LB parts
- Build file set-up, software and hardware needed for PBF-LB processes
- Powder handling
- Laser beam characterization
- Post processing
- Maintenance of the system
- Quality assurance in PBF-LB
- Health and safety in PBF-LB processes

Professional profiles

An overview about a certain profession. It contains a general description of the main objective of the profession, it's general responsibilities and tasks

Qualification

Demonstrated education, training and work experience, where applicable. An official record of achievement awarded on the successful completion of a course of training or passing of an exam. It confirms a quality, ability, or accomplishment that makes a person suitable for a particular position or task

<i>Skills</i>	Ability to apply knowledge and use know-how to complete tasks and solve problems
<i>Supervisor</i>	A person who has a lot of experience, knowledge, or skills in a particular subject that supervises the overall Additive Manufacturing process at industrial level
<i>Work Package Leader</i>	A designated person who is the leader of a WP consisting of representatives from different organizations which are all belonging to the project consortium. He / she is responsible for the coordination of participant's activities in different working groups (organizations)
<i>VET Provider</i>	A VET provider is any organisation or individual providing training services including schools and universities providing professional training courses. VET providers should be able to react to rapid changes through use of new technologies, to be more effective in their response to stakeholders' needs, and to exchange experiences and learn from others in order to be more competitive in their community