SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

2nd Report on the Analysis and Validation of Needs

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1. Executive summary

Implementing Additive Manufacturing (AM)/3D printing requires preparing the coming workers and reskilling the current workforce in order to successfully adopt these technologies. In this sense, it is needed to better anticipate the current and future AM skills needs at manufacturing workplaces in Europe.

Along SAM project data collection and feedback phase, the gathered skills' gaps and shortages were framed according to different scenarios:

- Scenario 1: Real case, in which extent skills need to be addressed in less than 6 months.
- Scenario 2: Short-term, how relevant skills / trends need to be addressed in the less than 2 years.
- Scenario 3: Foresight scenarios, how relevant skills / trends need be addressed in the future, within the next 10 years.

The current report constitutes the **baseline to identify skills gaps and demands** of the **AM** Sector **for the real case and short-term scenarios**. This second Report on the Analysis and Validation of Needs, corresponds to the 2nd round of auscultation using surveys and interviews with key target groups, namely companies, AM workers, training organisations and recruitment agencies from June 2020 to April 2021.

Four criteria were used to determine the priorities to tackle the identified skills needs and gaps, which were: sectors relevance in alignment with ISO activities, urgency, impact on employability and relevance towards raising awareness on AM. The validated data on skills needs are used as reference to support the European AM Skills Strategy and to revise existing training programmes of the International AM Qualification System (IAMQS) and develop new ones.

In a nutshell, the skills gaps and demands for each scenario and target group are summarized below:

Skills	**Addressed in AM Courses** (Source 2019 survey)	**AM Workers Skills Gaps** (Real Case and Short-term Scenario survey, 2020- 2022)	**AM Companies Skills Gaps** (Real case Scenario 2020 survey)
Technological	• AM Processes • AM Applications Design (CAD Modelling) • Materials analysis and characterisation	• AM processes • AM applications • Materials' analysis and characterization Design	• Post-processing • Certification and validation, standards and costs
Entrepreneurial	• Creativity • Working with others • Learning through experience	• Learning through experience Working with others • Vision Spotting opportunities	• Creativity Financial and economic literacy • Working with others
Green	• Eco-design, • Circular economy • Life Cycle Analysis (LCA)	• Resource efficiency management • Circular economy	• Life Cycle Analysis (LCA) Circular economy Resource efficiency management
Digital	• Cybersecurity • Ability to think 3D	• Ability to think 3D, • Digital data management Digital data analysis	• Ability to think in 3D • Digital data analysis, • Digital data management

New knowledge on trends until 2022 for AM Workers (survey, 2020- 2022)	• **Materials** namely towards the implementation of new applications and products for all materials; related to the development and standardization of new materials; multi-material parts; • AM processing namely about AM machines for multi-materials; multi-functional parts incl. Parts with embedded sensors, hybrid machines and faster AM metal machines; • Post-processing namely processing trends, new quality standards, design to minimize post-processing, improved heat treatments as well as new surface finishing and automation of support removal; • ICT and quality control related to improved AM process control, new inspection techniques and advanced monitoring systems.

	Materials	**Required AM Professional Profiles**	**Future upskilling needs**
AM Companies (2020 survey)	**Metals followed by Polymers**	**Process engineer, the AM designer and the materials engineer**	**R&D staff** and **quality managers** on technological aspects such **as standards, post-processing, design and the AM process**
	AM Occupations (Both Metal AM and Polymers)	**Sectors with more job demands**	**Growth of AM demand**
Employability in AM (Recruitment Agencies Survey, 2021)	Process engineer, Designer, Materials engineer and Operator/Technician	Automotive and Aerospace	Demand for AM professional has grown 21-30 % from 2019 to 2021

The next activities to be undertaken in SAM project forecast in 2021 and 2022, foresee the continuous identification of current and short-term needs with industrial organizations, AM professionals/workers, training organizations and Research Centres to map the relevant AM skills gaps and needs.

2. Introduction

SAM project is a strategical approach to skills in AM, which is developing a dynamic forecast methodology focused on skills gaps, shortages and mismatches identification, anticipation and validation, in order to develop and / or revise qualifications and profiles in AM with the engagement of relevant stakeholders within the European and National landscapes.

The 2nd round of forecast methodology addressed in SAM relied on a continuous market research to determine skills mismatches and gaps in the AM sector using a combination of methods with different target groups. The main auscultation was performed using a set of online surveys with representatives from industry, both employers and workers in AM, training organisations and recruitment agencies.

After collecting data, their analysis was performed during an internal workshop, thus defining the skills priorities and areas that needed further exploitation in the next stage of data collection. The last step of the forecast process consisted in the validation of skills needs with external stakeholders during a dedicated workshop. Complementary activities were conducted such as interviews with polymers Experts, enabling to analyse in more detail AM applications and solutions to tackle AM skills needs.

The current report, developed in the framework of the *AM Observatory* (Work package 4), gathers the main findings and conclusions taken from the application of developed forecast tools (Work package 2), thus constituting the baseline to define the activities to be implemented in the *Piloting of the methodology for creating and revising professional profiles and skills deployment* (Work package 5), 2nd stage of Real Case Scenario and Short-Term Scenarios.

The report is organised in the following parts:

- Section 3 “Applied Methodologies” - includes the description of the applied methodologies used in the skills forecast;
- Section 4 “Real Case and Short-Terms Skills Needs Results”– addresses the results achieved with each tool (e.g. surveys, interviews and workshops). The results on AM training practices, skills needs and Employment Data are given separately, as they were covered by specific surveys for each target group (e.g. industry representatives, workers, organisations involved in training activities and recruitment agencies) and in different periods.
- Section 5 “Results Comparison” - addresses the comparison between findings, namely the comparison of needs evaluation from 2019 to 2021, the training, industry and recruitment agencies surveys results and the industry vs workers survey results.
- Section 6 “Conclusions”- addresses the validation of results, main conclusions and reflection on the next steps, thus pointing out the priorities to follow in SAM to address the development of skills, profiles and qualifications in AM.
- Section 7 “Annexes” - includes all annexes and supporting documents (e.g. workshops agendas and the list of participating organisation).

3. Applied Methodology

The current chapter on the methodology, describes the conditions in which the tools for AM data collection and analysis were applied.

3.1 Surveys

The implementation of surveys was the main tools used for gathering data among stakeholders. Only online surveys were conducted, which were promoted through personal emails, included in newsletters and disseminated during specific events and networks, such as the the AM-Platform, CECIMO, EPMA, EWF, among others. Also, a QR code was created to facilitate the access via smartphone or another electronic device.

Four surveys were carried out from June 2020 to April 2021, aiming at different objectives and target groups, namely:

- **Survey on AM Training Practices** (from July to December 2020) **-** to understand and map educational practices deployed by **Training Organizations** concerning AM training in Europe;
- **Workforce Industry Survey** (from July 2020 to October 2020) to find out skills demands related to AM among **current professionals**
- **Industry Survey on AM Skills** (from August to December 2020) **–** to find out **employers/industry** needs with regards to emergent AM professional profiles, skills and gaps;
- **Recruitment Agencies Survey** (from March to April 2021) – to find out among **Recruitment Agencies** which are the job opportunities and employability data concerning the AM in the labour market;

3.2 Interviews

Interviews were conducted as a complementary tool to the surveys, enabling to explore in more detail which skills needs are required to be developed in future training programmes. Interviews were conducted for two months, from, with representatives from industry selected according to the following criteria:

- At least a representative from each type of company (e.g. SME; Start up; Large company; industrial Association).
- Variability in terms of countries and gender balance.

The estimated duration of the interview was 30 minutes to one hour. A common script was used to conduct the interviews, which combined multiple choice and open questions.

After collecting data, they were analyzed during an internal workshop, then validated with Industrial experts during the working session, as detailed in chapter 3.1.2 and 3.1.3.

3.3 Workshop for data analysis

The **2nd workshop for data analysis** took place online on 3rd December 2020, during SAM 5th project meeting, where all partners participated. A specific agenda was established to guide the working session implementation (see Annex 1).

The workshop aimed at analyzing and discussing the results from the surveys, in order to conclude about the AM skills gaps, professional profiles to be addressed in the next six months and two years.

LAK, leader of WP5 (*Piloting of the methodology for creating and revising professional profiles and skills deployment*), was responsible for conducting the workshop introduction and groups moderation.

To facilitate the results analysis, three groups were set to discuss the different surveys results conducted with training centres, industry workers and companies. Partners were equally grouped into three groups, to guarantee expertise and gender balance.

Group 1 (composed by EWF, LMS, EC Nantes, UBRUN, Ansys and LAK) tackled the results from the training centres survey, aiming to characterize the current landscape of AM training, while group 2 (composed by ISQ, EPMA, IMR, LORTEK,

AITIIP, MTC and LAK) and group 3 (composed by IDONIAL, CECIMO, FA, POLIMI, Materialise and LAK), tackled respectively the results from the AM workforce survey and companies survey, thus focusing on the analysis of skills gaps, required professional profiles and /or qualifications and defining the priorities for the scenarios: real case (less than 6 months) and short term (less than 2 years) scenarios.

After the analysis, conclusions were presented by the rapporteur of each group. A detailed description can be found in the conclusions chapter.

Neither the interviews nor recruitment agencies findings were approached by the analysis, as they were performed afterwards.

3.4 Workshop for the validation of skills needs

The 2nd SAM workshop for the validation of skills needs took place online on the 27th January 2021, aiming at:

- promoting the awareness on SAM, and its latest results; importance at political and industrial levels;
- discussing about AM skills needs, future Qualifications and Trends considered as priority to support the growth of the sector;

To achieve these goals, the validation session used a combined approach consisting of a plenary to introduce participants to SAM objectives and results, followed by a hands-on activity with the Industrial Council Experts group (refer to the agenda in Annex 2 and the list of participating organisations in Annex 3).

During the hands-on, the moderator used *slido* to launch and monitor the discussion, which was supported by a guiding script containing the summary information on each topic.

A detailed description on the workshop conclusions can be found in chapter 4.

4. Real Case and Short-Term Skills Needs Results

The survey's results targeting short-term skills needs are described in this chapter, covering the auscultation of AM Education and Training Providers, AM Workers and AM Companies. The applied surveys address several topics, such as General information and background, AM training activities, AM skills and professional profiles needs, relevance of the different categories of skills, AM Employability among others.

4.1 Findings on the surveys conducted with Training Organisations

The survey was open from July to November 2020, gathering a total of 96 responses.

General information and background

All organizations replying to the survey were located within Europe with the majority of them 24% being in Spain, followed by France with 18% (see **Error! Reference source not found.**). In terms of type of training provision given, the majority of organizations are Universities (53%), followed Research Centres (15%), Technology Centres (11%), and Private Training Centres (10%).

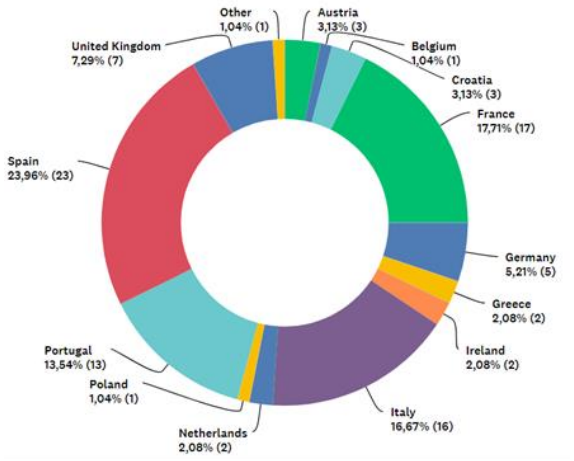


Figure 1 -Participants Country Origin

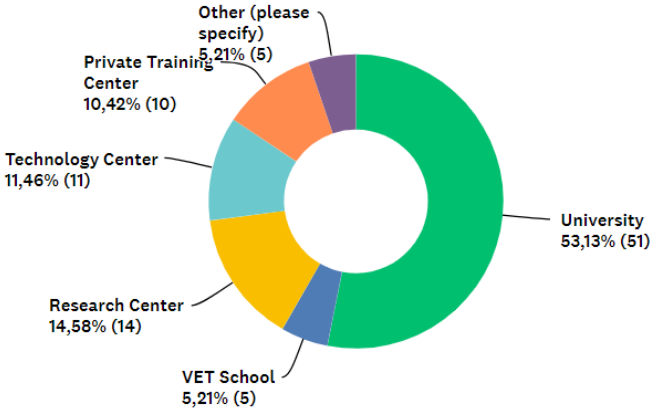


Figure 2 -Types of training centres

In terms of **general training delivery focused on specific sectors** (see Figure 3)**,** organizations providing courses mainly target the industrial equipment and tooling sector with 68% of replies, followed by the automotive sector (59%), and Aerospace (50%).

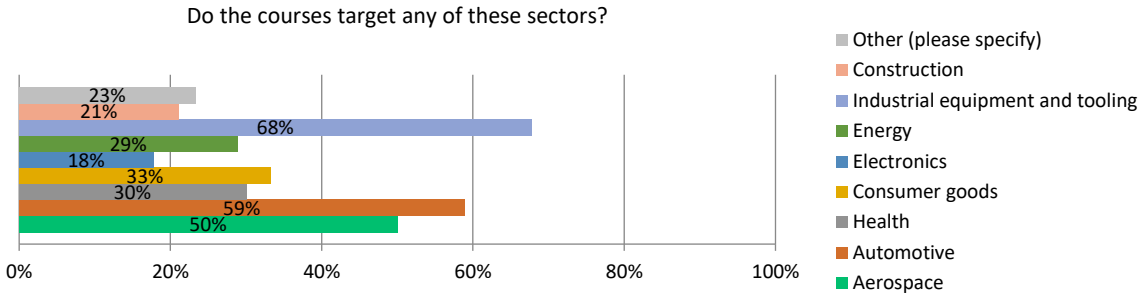


Figure 3 - Targeted sectors in general training activities

Participants were asked to indicate the number of students trained every year by their organisation (see

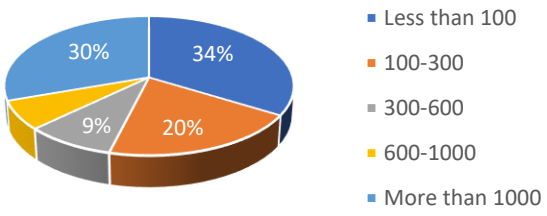


Figure 4 -Number of Students Trained in AM Yearly

.) From the 89 responses received, it can be derived that 34% of the respondents' train less than 100 students on a yearly basis. However, 30% train more than 1000 students, while 20% is training between 100-300 students each year.

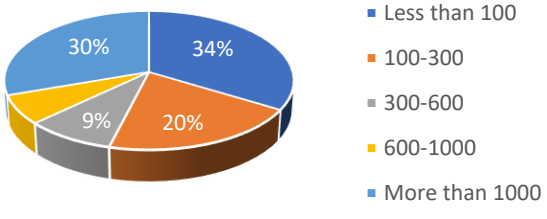


Figure 4 -Number of Students Trained in AM Yearly

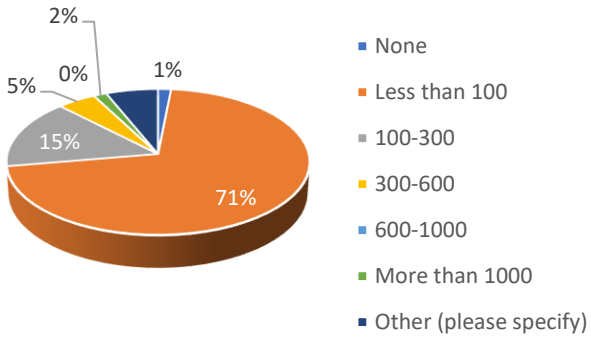


Figure 5 -Number of Students involved in AM Training

From the above number of students trained every, the majority corresponding to 71% of the training centres have less than 100 participants each year participating in AM courses (see **Error! Reference source not found.**).

Regarding the training practices, 65% of training centres offered specially AM courses. There were 22% of the participants stating their courses did not focus on AM but were related to and 13% answered that their courses did not focus on AM (Figure 6).

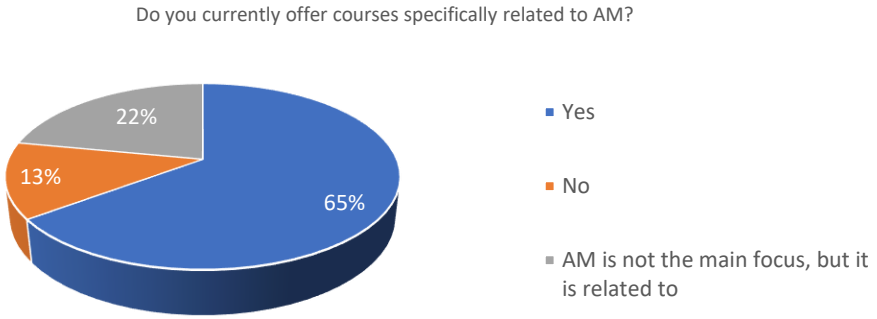


Figure 6 Relation of the courses with AM

To identify the major obstacles in AM education and training, participants that did not deliver AM courses were asked to identify the main reasons. The major reason identified with 45% of the responses was the general lack of requested training, followed by 36% that identified the lack of AM equipment, whereas the lack of trainers was only 9% of the response (see

Figure 7).

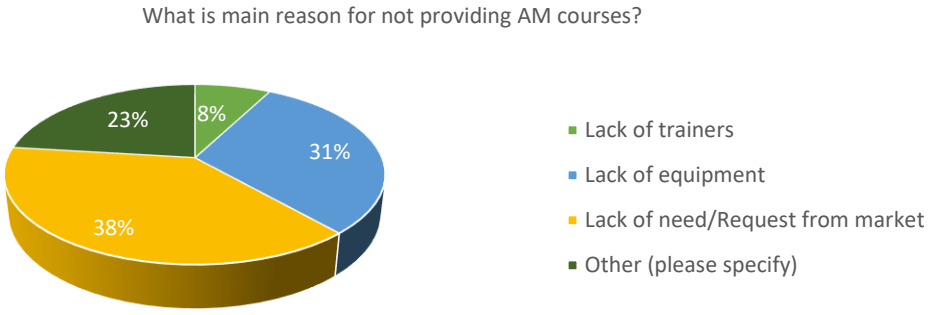


Figure 7 Main reason for not providing AM courses

More analytically, this lack of requests towards AM training, mentioned by the majority of the respondents, can be justified in two opposite ways: i.) either the training offers are low and do not fit to the costumers needs; ii) either the number of training centers giving AM courses is huge enough to generate the diffusion/ fragmentation within a certain country or region, thus given the impression that there is a lack of demand. As it concerns the lack of AM equipment whereas the lack of trainers. Obviously that in addition to the lack of equipped training centers, the lack of training offers and demand from the industry are important aspects to consider when analysing skills gap driver. To conclude, the preparation of the European, National and Regional Training organizations in terms of equipment and qualified personnel is a crucial objective to tackle the challenges of AM for qualified personnel.

Additive Manufacturing Training Activities

The AM education was initiated in the form of complementary courses and as optional programmes in major engineering degrees. The certain standalone aspects of the AM technologies (e.g. Design for AM) made it possible to be delivered online in the form of online courses and webinars.

Up to date, 27% of the organizations mentioned to be conducting AM online training. The face-to-face approach provided by an education centre was also preferred from the 57% of the responder's (

Figure 8).

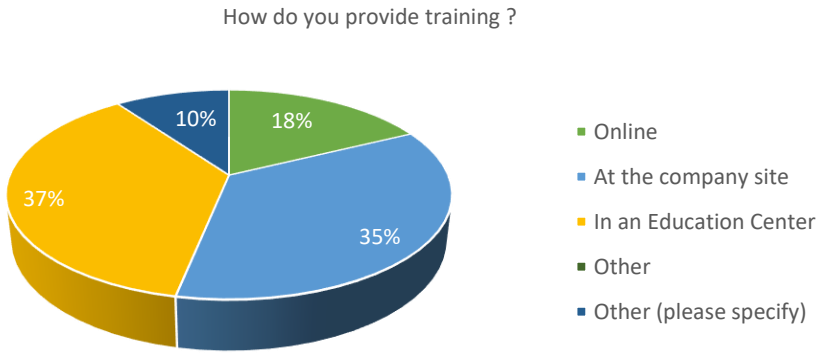


Figure 8 AM Training Nature of Delivery

From the respondents that selected other options, most of them provide trainings at the facilities of the client or at their own. The training providers deliver their training at customer's premises or at the training centre itself. From the sum of the answers, it can be concluded that individual providers used several ways to offer training (at company site/education centre or as mixture of presential and online-training, e.g. blended learning).

In terms of targeted levels, there was a clear focus on higher qualification levels in the educational provision for AM and thus the majority were assigned to the level of the Bachelor's or Master's degree. The majority of the offers were for EQF Level 7 with 45% of the responses targeting a Master's degree level, assuming these were mainly offered by universities (see Figure 9).

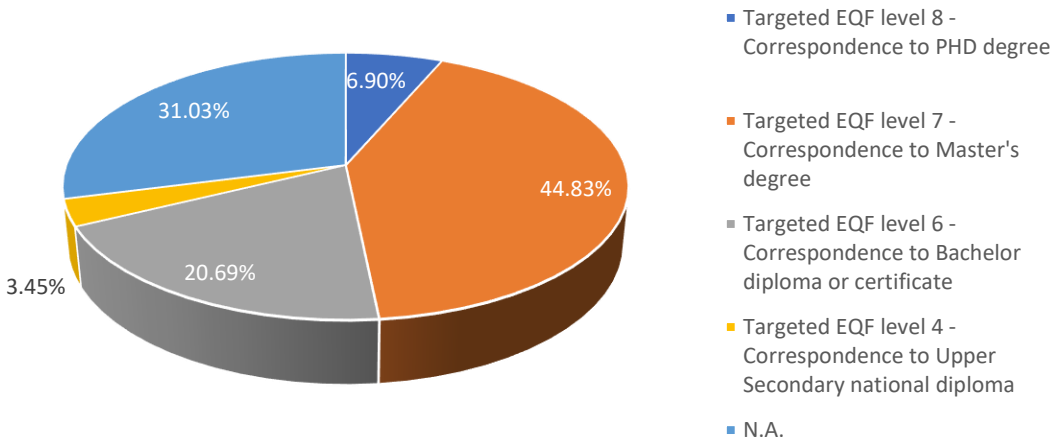


Figure 9 - Targeted AM Training Levels, according to Survey to the Training Centres

While AM is already very well represented in academia, there are hardly any offers for the level of vocational qualification of EQF level 4, typically offered by vocational schools and continuing vocational education and training providers and none for EQF level 5.

Another question dedicated to the nature of the AM training and education was about the duration and the characteristics of the AM courses. The majority (45.83%) responded that they provided only short-term courses targeted to specific AM aspects of the technologies, follows the rate of 37,5% of both short and long term courses.

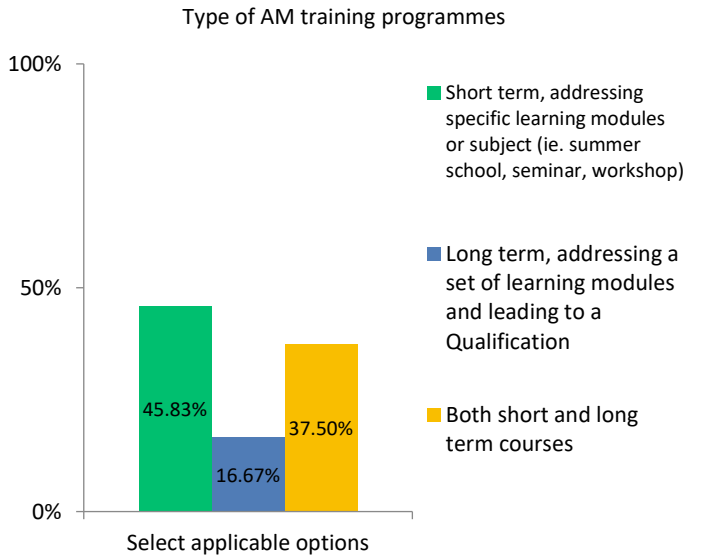


Figure 10 - Type of training courses preferred to be offered

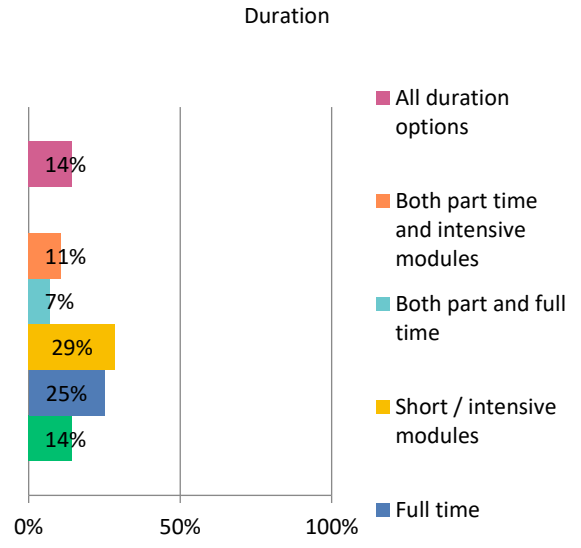


Figure 11 -Preferred duration of the training courses offered

Finally, 16.67% answered that they offered long term, addressing a set of learning modules and leading to a Qualification (see **Error! Reference source not found.**). As it concerns the duration of the courses, 29% answered Short / intensive modules as the duration of courses and 25% answered Full time courses.

Participants preferable training mode of delivery is the Presential Learning / classroom lectures, indicated by 93% of the respondents (see Figure 12).

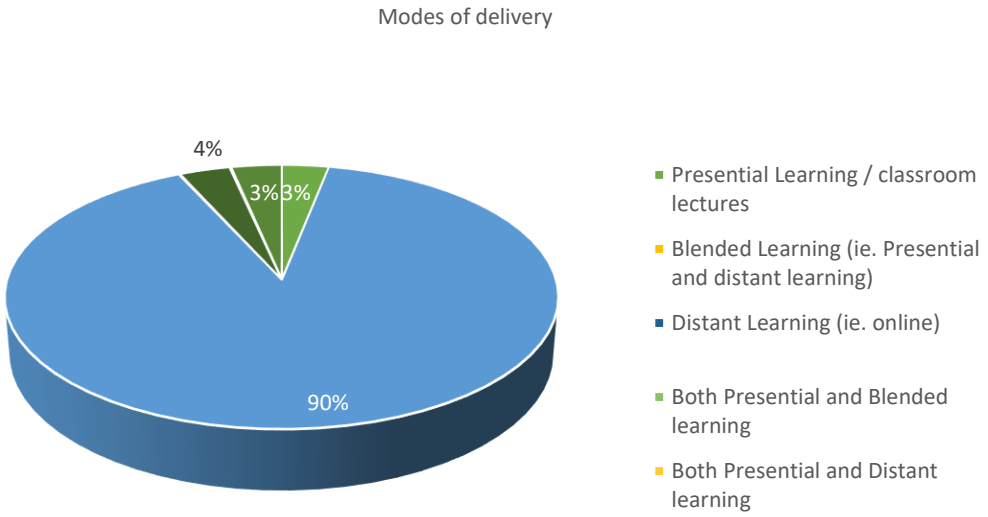


Figure 12 Modes of the offered training courses

The current training survey indicated which **subset of skills** were mostly addressed in the courses because of gaps or demands to be taught. Four categories of skills were addressed in this analysis, namely: **technological, green, digital and entrepreneurial**.

In the field of **Technological skills** (see **Error! Reference source not found.**), 91% of respondents mentioned their courses addressed AM processes, followed by AM application with a rate of 85%. Two significant AM skills are lacking in the training offer, as only 18% of respondents indicated that Certification and Validation was addressed in the courses related and 35% for Testing and Quality control. This is an important information which should be considered in the future.

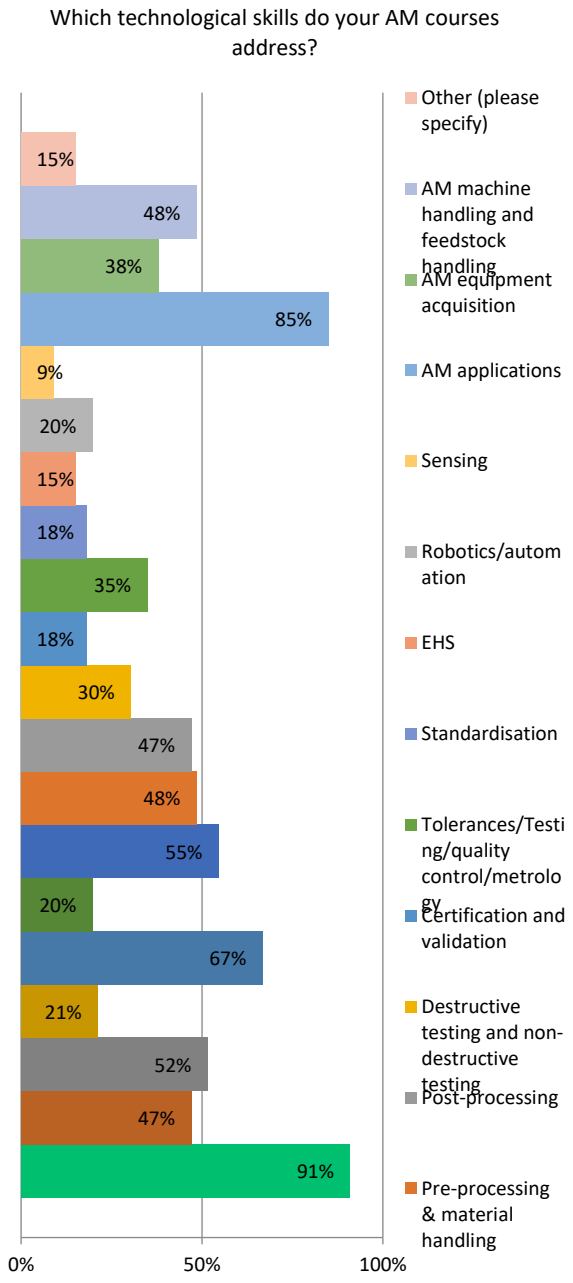


Figure 13 -Technological skills addressed by the AM courses

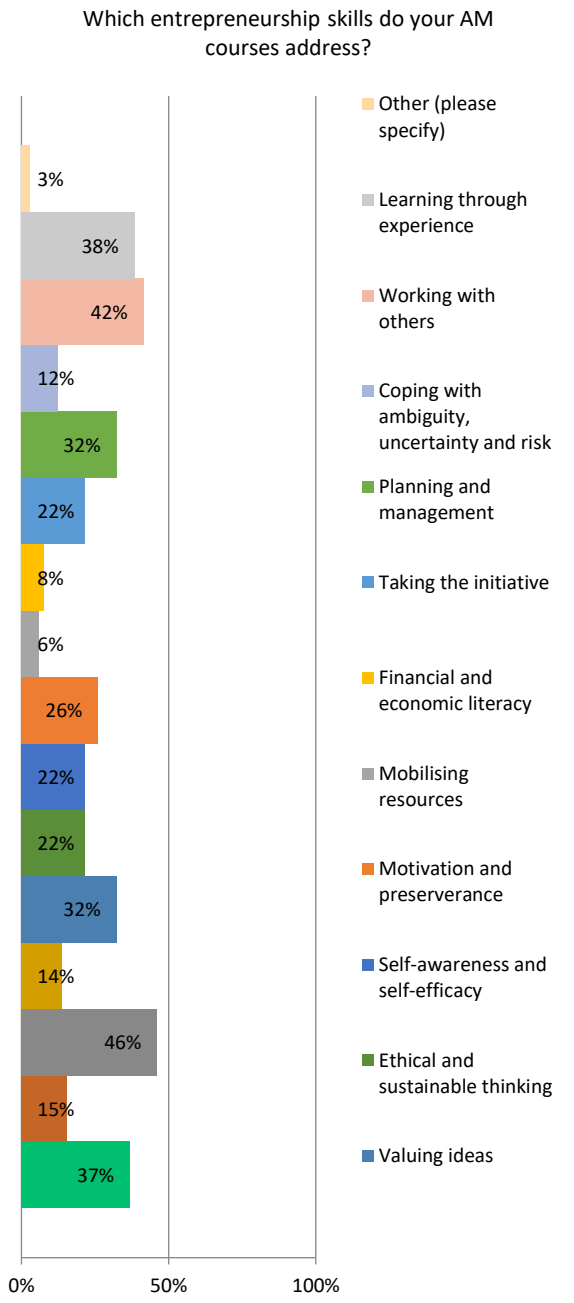


Figure 14 - Entrepreneurship skills addressed by the AM courses

Within the **Entrepreneurship skills**, Creativity was the most addressed skills in the training courses, according to 46% of respondents, followed by Working with other 42%. The least one being taught in training center was Mobilizing resources with a rate of 6% (see **Error! Reference source not found.**).

For **Digital skills** (see Figure 15**Error! Reference source not found.**), the Ability to think 3D, received the bigger rate of 69% of respondents, who mentioned its presence in the training courses, followed by the answer that course did not address any specific digital skills with a smaller rate of 27%. However, the least digital skills taught in training centre was Cybersecurity with 5%.

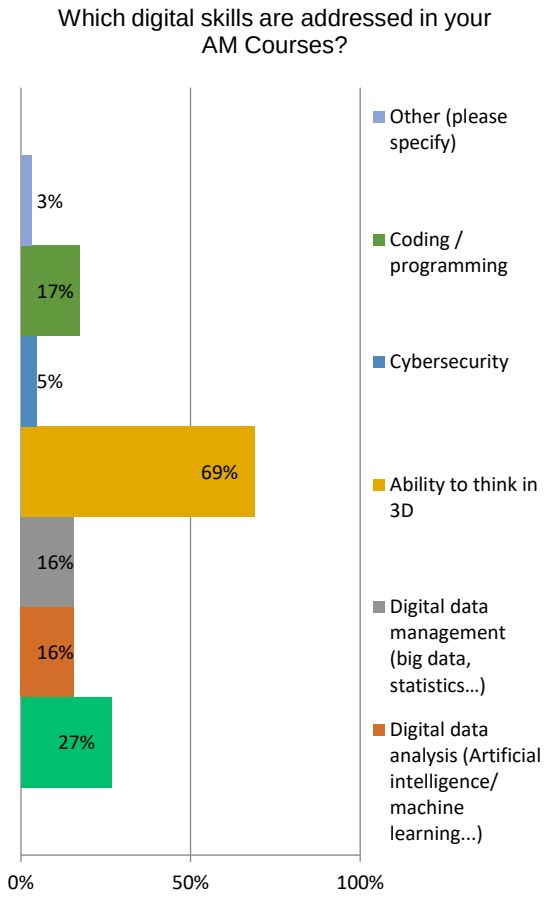


Figure 15 -Digital skills addressed by the AM courses

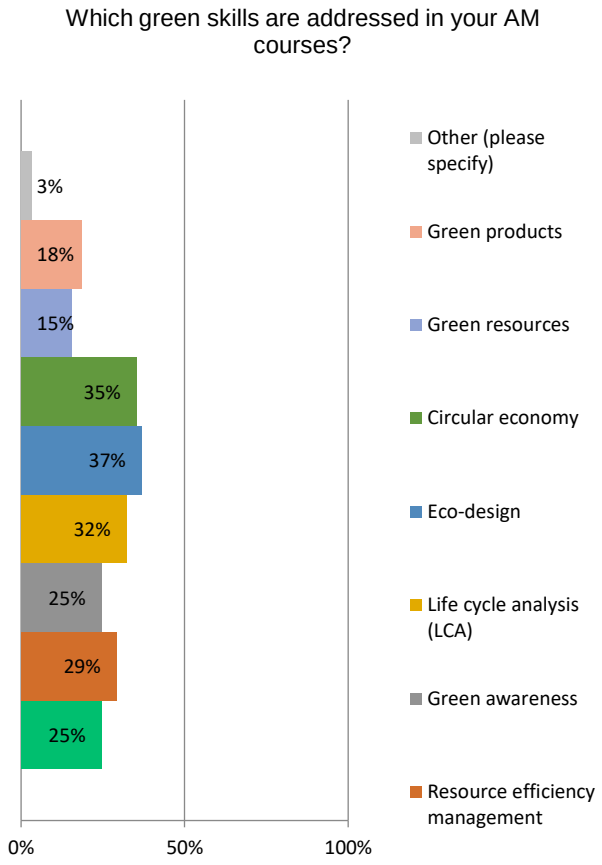


Figure 16 -Green skills addressed by the AM courses

For **Green skills** (see Figure 16), Eco-design received the majority of the answers with 37%, followed by Circular economy 35%. The least one being taught was green resources 15%.

In terms of mechanisms, to keep track on trainees after the end of the course, a significant part of the answers was that the **tracking mechanisms depended on the course** with a rate of 41%. Additionally, a really good number of participants (38%) answered that they keep track the trainees (see Figure 17**Error! Reference source not found.**). Also it was asked to identify the mechanisms they used to keep track of their students and trainees. The majority responded via **follow up questionnaires** (see **Error! Reference source not found.**).

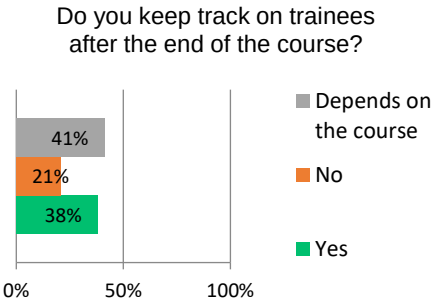


Figure 17 -Tracking on trainees after the courses

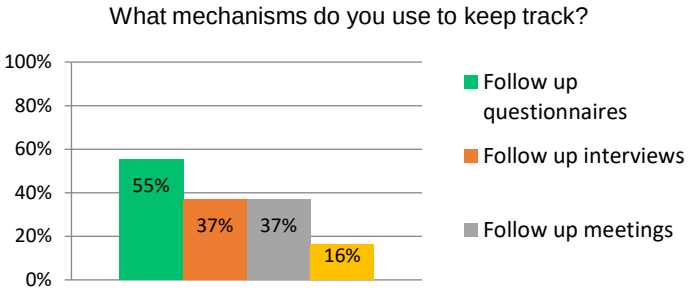


Figure 18 -Mechanisms for Tracking AM Education

The "Other" responses that were specified mentioned follow up mechanisms such as emails, alumni associations and via social media channels and tools (e.g. LinkedIn).

It is worth noting that approximately half of the survey participants (49/96) answered this question. Judging from the plethora and variety of the available multiple answers it can be assumed that the rest of the organizations do not apply tracking mechanisms or follow up procedures for their AM training and education activities.

Learning and Assessment Tools in AM Training

The results gathered through the training survey brought an awareness about the relevance of different learning /training tools and evaluation methods in the existing AM training programs, according to the targeted categories of skills.

Globally, it could be observed that combined learning approaches were used for all categories. Still, results showed that **Lectures** generally were the most common approach in training for the different categories of skills (see Figure 19). For example, regarding the **technological skills** participants confirmed they were addressed at 89% by lectures. **Case studies** received also a satisfying rate of 61% for Technological skills and 59% for Entrepreneurial skills. **Practical activities** in Laboratory received a high rate of 75% for Technological skills. In contrast the least used approach in training for the mentioned skills was **Visit site**, not surprisingly, its usage rate was very low for Digital skills.

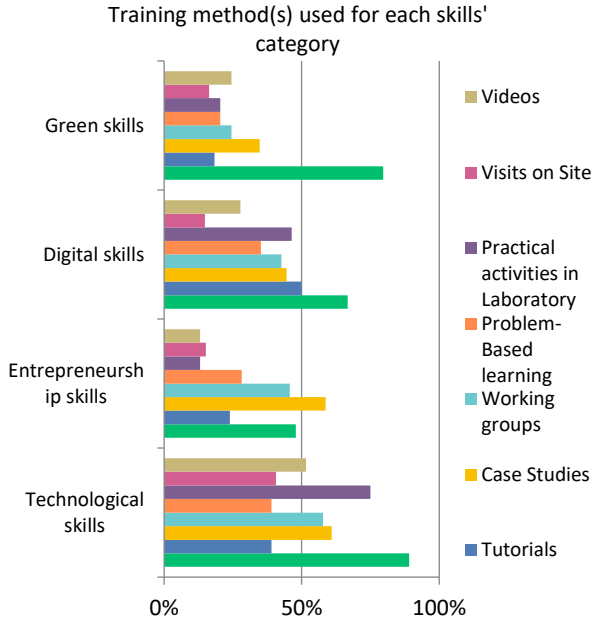


Figure 19 - Training method(s) for each skills' category

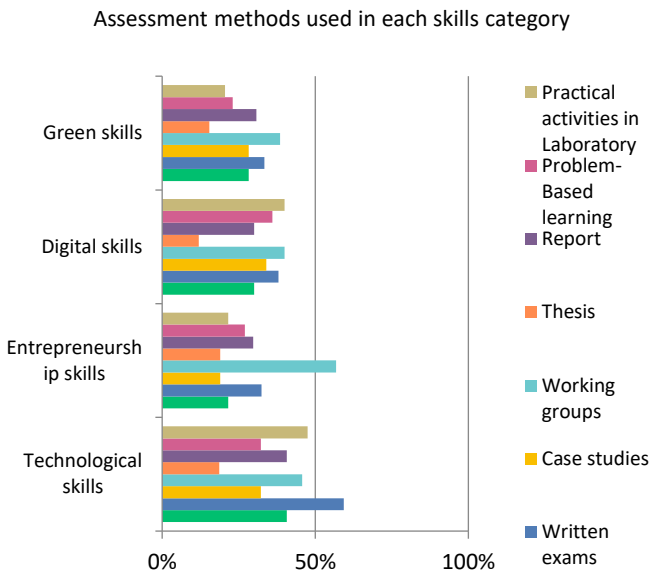


Figure 20 -Evaluation methods, relate each type of skills with the assessment methods used

Training survey gauges the relevance of different assessment methods used in AM training to evaluate the learning outcomes for the targeted categories of skills. The results (see Figure 20) showed a combination of methods and tool. The most used method was Writing exams with a rate of 59% for Technological skills, followed by working groups activities for Entrepreneurship skills with a rate of answers 57%. The least one applying assessment approach was the Thesis with only 19% for Technological and Entrepreneurship skills. On the other hand, among common tools/methods, Laboratory practices was a leading solution in both training and evaluation, while Problem Based Learning was got less attention.

Globally, in terms of assessment methods and tools, the Working groups were a dominant (17%) followed by written exams (16%)

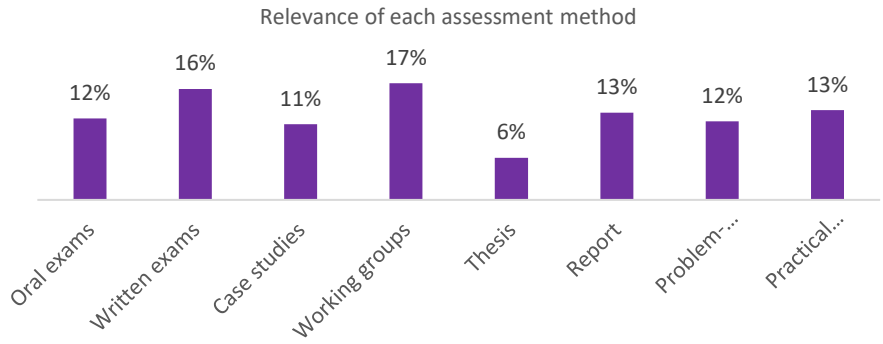


Figure 21 Relevance of different assessment methods for the targeted skills

Analysing data in more details concerning each skills category.

Technological skills

Training survey gives some information about in-use training tools and evaluation methods for Technological skills. The tools which were used the most in teaching technological skills were Lectures 89% and Laboratory practices 75%, but the least ones were Problem Based Learning and Tutorial both with 39% (see Figure 22). In terms of assessment for evaluation method, the most one using was Writing exams (59%), followed by Laboratory practices (47%) and Working groups (46%). The least one applying was Thesis with only 19%. On the other hand, among common tools/methods, Laboratory practices was a leading solution in both training and evaluation, while Problem Based Learning was got less attention (see Figure 23).

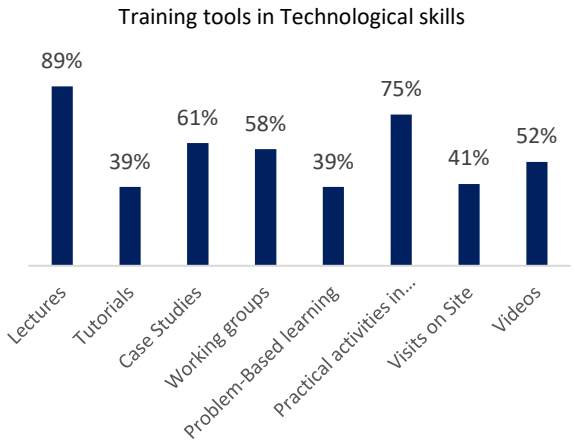


Figure 22 -Training tools in technological skills

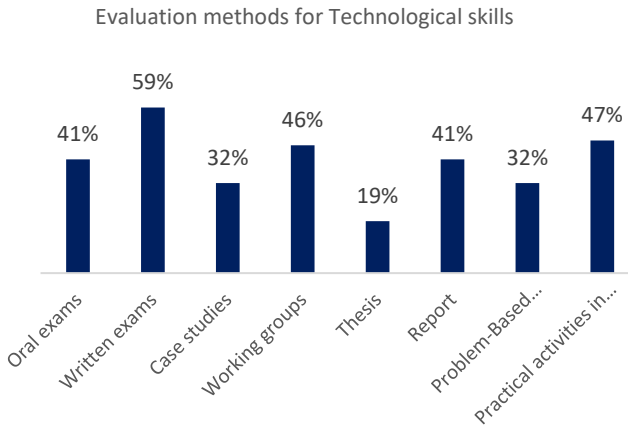


Figure 23 -Evaluation method in technological skills

Entrepreneurship skills

Training survey gives some information about the in-use training tools and evaluation methods for Entrepreneurship skills. The tool which was using the most in teaching Entrepreneurship skills was Case study 59%, and the least ones which were using were Laboratory practices and Videos, 13% for both (**Error! Reference source not found.** Figure 24Figure 24). As evaluation method for the Entrepreneurship skills area (see Figure 25), the one which was applying the most was working groups 57%, and the least ones were Thesis and Case studies, only 19% for both of them. On the other

hand, among common tools/methods, however Case study was the most popular training tool, it was the least applicable one for evaluation method. Laboratory practices was taken less attention in both training and evaluation. In contrast with Laboratory practices, and Working group was an attractive solution for both of them.

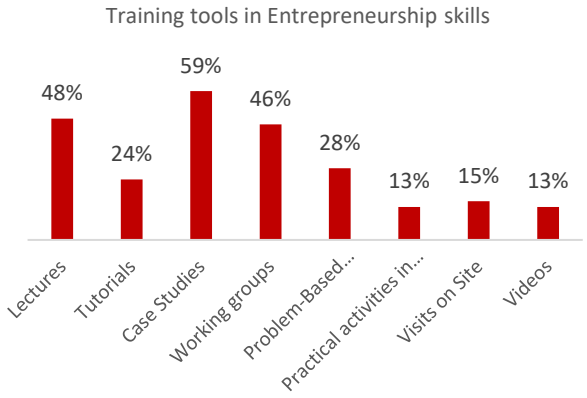


Figure 24 -Training tools in Entrepreneurship skills

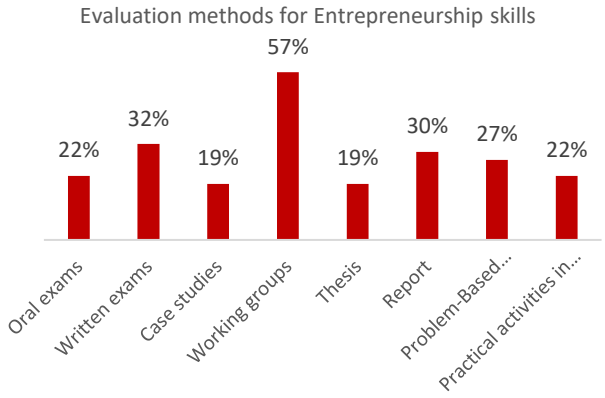


Figure 25 -Evaluation methods in Entrepreneurship skills

Digital skills

Training survey gives some information about in-use training tools and evaluation methods for Digital skills. The most used tool in teaching Digital skills was Lectures 67%, and the least one was Visit on site 15% (see Figure 26). For evaluation method, the most ones which was applying were working groups and Laboratory practices, 40% for both, followed by written exam 38%. The usage percentages of all evaluation methods were in a range between 30% and 40%, the only exception was Thesis, the least popular one with only 12% of usage. On the other hand, among common tools/methods, Laboratory practices was indicated as an attractive solution in both training 46% and evaluation 40% (see Figure 27).

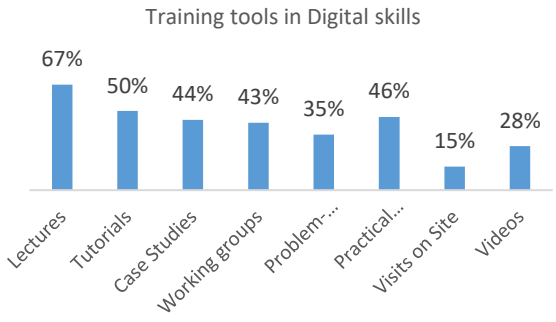


Figure 26 -Training tools in digital skills

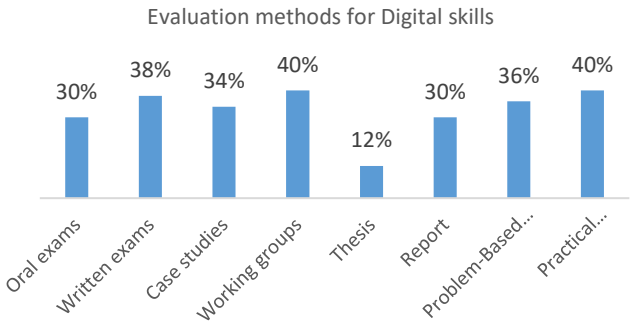


Figure 27 -Training tools in digital skills

Green skills

Training survey gives some information about in-use training tools and evaluation methods for Green skills. The tool which was using the most in teaching Green skills was Lectures 80% with a significant distance from the other tools where the next most attractive one was Case studies 35%, and the least one using in teaching Green skills was Visit on site 16% (**Error! Reference source not found.**Figure 28). For evaluation method, the method which was applied most was Working groups 38%, followed by Written exam 33%, and the least one applying was Thesis 15% (see Figure 29). On the other hand, among common tools/methods, Problem-Based Learning and Laboratory practices were two solutions taking less attention in both training and evaluation.

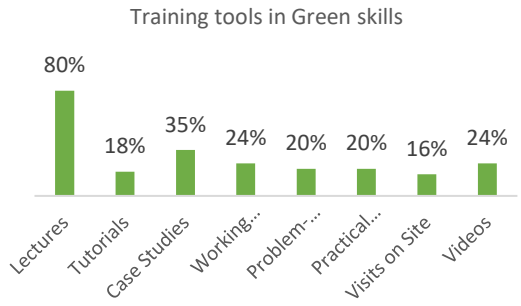


Figure 28 -Training tools in green skills

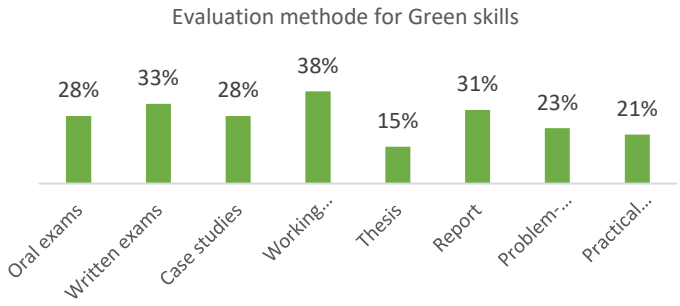


Figure 29 -Evaluation method for green skills

Alignment between companies and workers skills needs

In terms of AM related courses domains preferentially requested by both companies and workers, the results reveal an alignment between their needs.

For instance, the AM process is the most demanding course, where 85% of respondents mentioned it as the main domain of courses requested by companies, followed by Design (CAD Modelling) 61% and AM applications 59%. Certification and Validation was indicated by 41% respondents as the main domain of courses requested by companies, and a rate of 20% for Testing/quality control skill (see Figure 30).

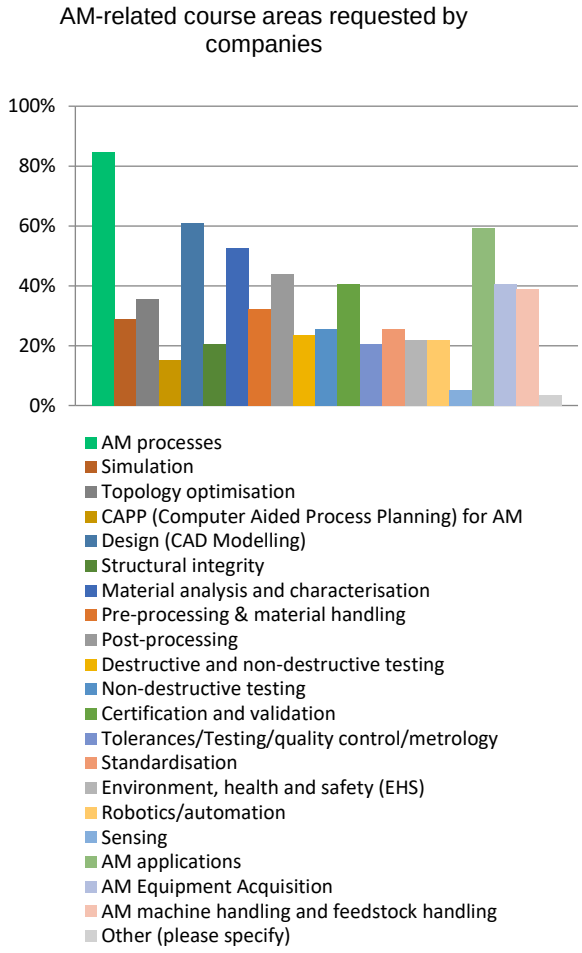


Figure 30 -Main AM-related course areas requested by companies

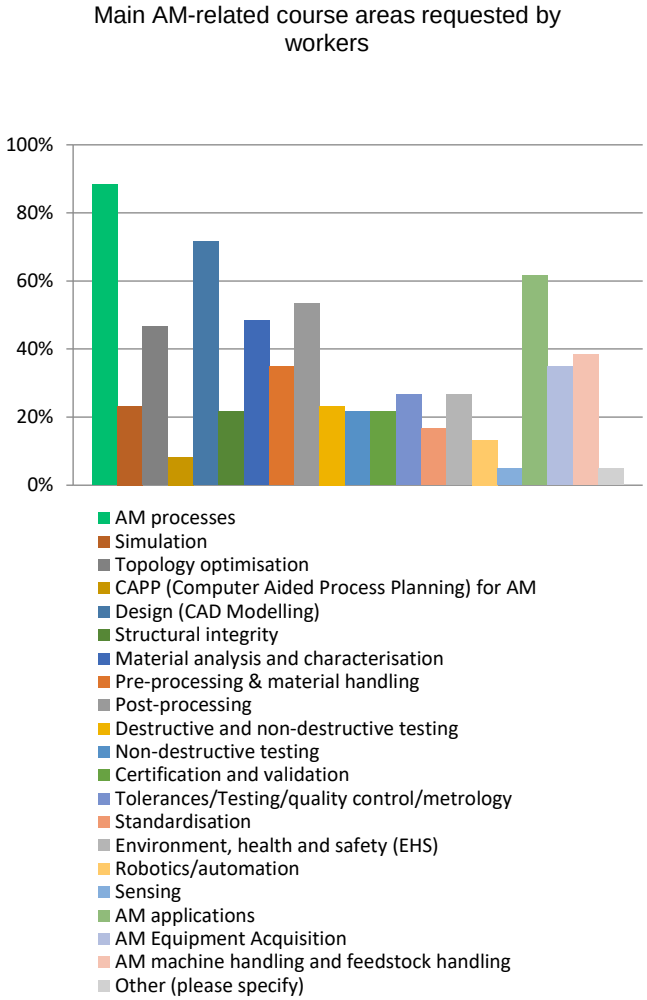


Figure 31 -Main AM-related course areas requested by workers

Findings indicate that AM Courses provided for technological skills seem to be market-oriented, as the top three technological skills addressed in training are also the most requested by companies and workers. More analytically, like the main courses requested by companies, the respondents mentioned AM process as the most demanding course domain requested by workers with a rate of 88%, followed by Design (CAD Modelling) 72% and AM applications 62%. In addition, the percentage rates for two significant AM skills are lacking, indicated by Industry survey, 22% and 27% for Certification and Validation and Testing/quality control, respectively (see Figure 31Figure 31). As mentioned in the above chapter of Tracking AM Education, the major obstacles identified in the delivery of training by those organizations that don't provide AM training yet (corresponding to 12 % of the respondents) are linked with the lack of requests (45%) and the lack of AM equipment (36%), whereas the lack of trainers was only 9%.

4.2 Findings on surveys conducted with the AM workforce

The survey with industry workers was carried out from July to November 2020 among AM workers. A total of 138 participants responded to the survey.

General information and background

In terms of general information and participants' background, the first question dealt with the type of organisation in which people are working. As it can be observed (see Figure 32**Error! Reference source not found.**) half of the respondents classified as "other" corresponding at Higher Education Organizations/Universities, Research Centre and Non Profit Association, followed by "large companies" and SME´s (around 20 %)

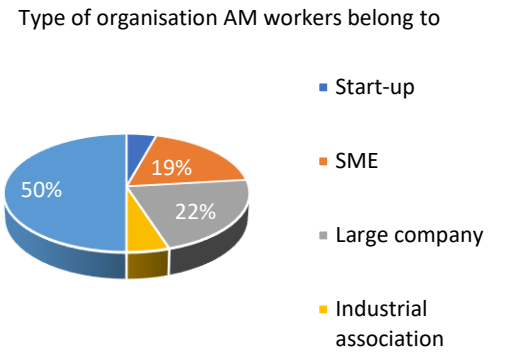


Figure 32 -Type of company represented by AM industrial workers

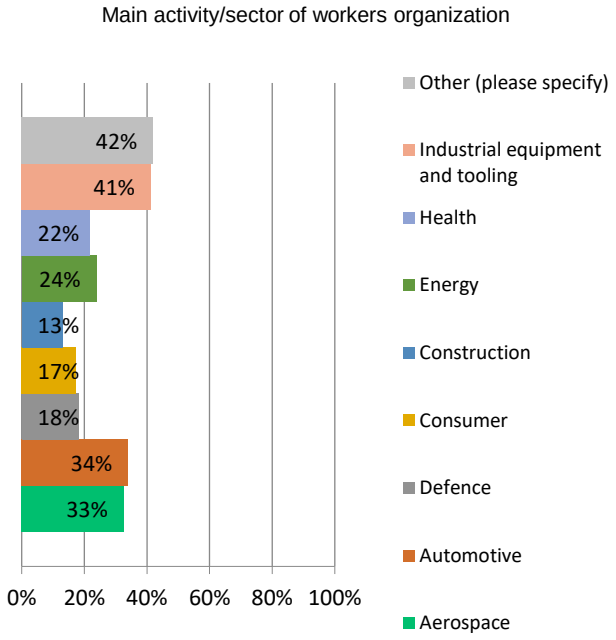


Figure 33 -Main sectors represented by AM industrial workers

In terms of most represented sectors of activity (see Figure 33), they correspond to "Others"(42%) identified as the Education, Research and Development, Architecture; Maritime, Sport; Software Industry, Oil and Gas, Transport, Robotics and Biomedical (58 answers) sectors, followed by the Industrial Equipment and tooling sector (41%), Automotive (34%) and Aerospace (33%).

The respondents were able to name more than one activity sector. Hence, these values are not conclusive in terms of the most represented sectors on the generality of the AM market in Europe. The main participants of the survey were from Spain (33 %) and the United Kingdom (18 %). Those numbers were followed by France and Germany (8% and 6 %).

As it can be seen (Figure 34), 64% of the responders listed "Research and Development" as their main value chain segment. "Other", end-users, OEM and service bureau were indicated with around 7% each.

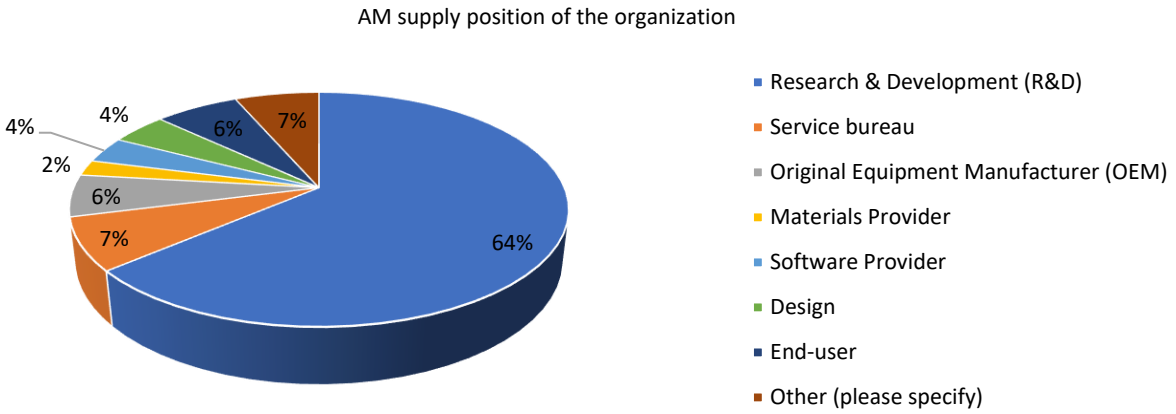


Figure 34 - Value Chain Segment's AM industrial workers are involved in

The profile of the respondents was very diversified (see Figure 35). Ranging from process engineer (20 %) to Operator/Technician (4%). Out of the respondents, the majority (76%) had never changed their role in AM. Furthermore, 55% never received training on the role. For those who did receive training, the majority received training on processes (73%) and Materials (60%). However, a significant amount also received training in post-processing and design (each 40%).

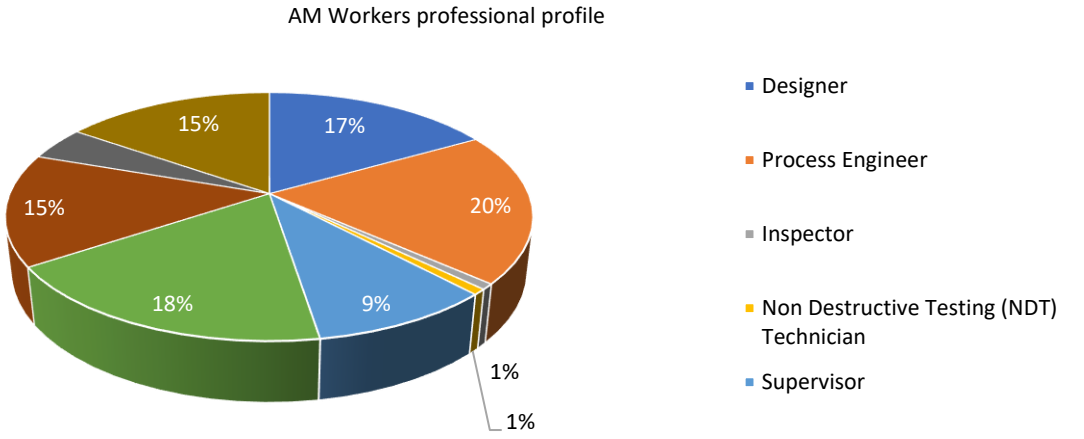


Figure 35 - Professional Profile of the AM workers

The majority of the respondents has worked in AM for 1-5 years (59%) and their education background is mainly Master (54%) and Doctoral (29%).

Considering the profile of the AM workers described above, further details were explored in terms of AM knowledge and expertise (see Figure 36).

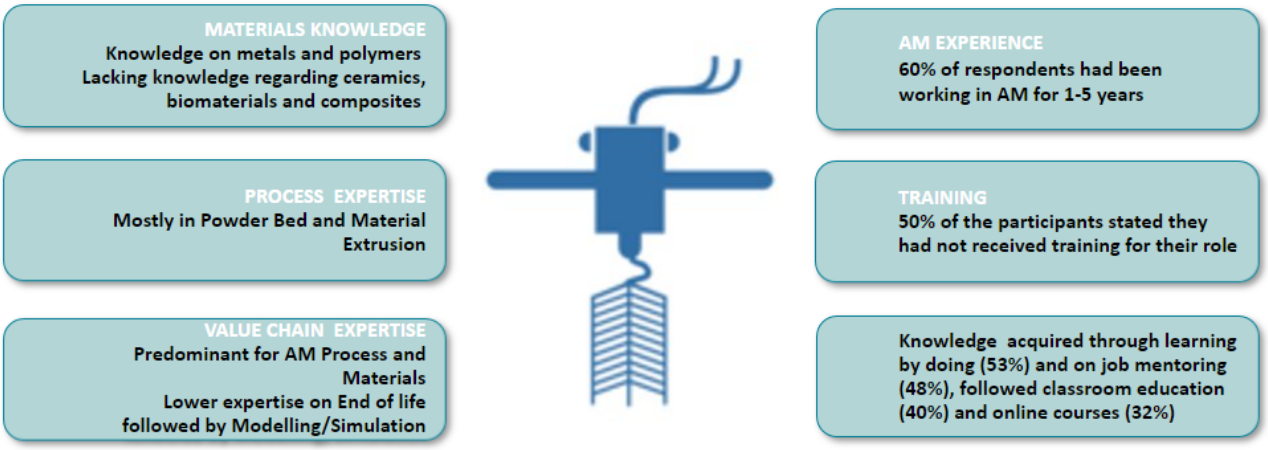


Figure 36 - Overview on AM Workers Profile

Whereas for the single process steps in AM, the expertise is quite well distributed, the majority of the people exhibit only limited knowledge for Composites, Biomaterials and Ceramics. Over 50 % of the respondents rated their knowledge for Polymers and Metals as high or very high (56% and 59% respectively). This is not a surprise that processing with composites, biomaterials and ceramics is still considerably low (see Figure 37).

In terms of processes, Binder Jetting and Material Jetting have not been known much – the percentage for no and low expertise in these processes is 58% and 63% respectively. The most well-known process is PBF. 35% of the respondents stated that they have very high knowledge in it (see **Error! Reference source not found.**Figure 38).

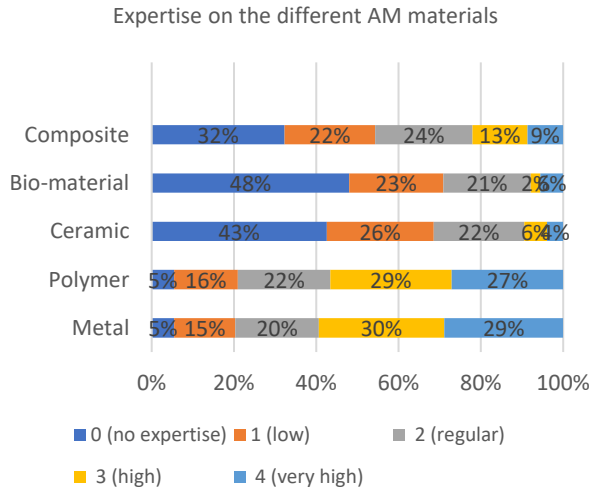


Figure 37-Expertise in Different AM Materials

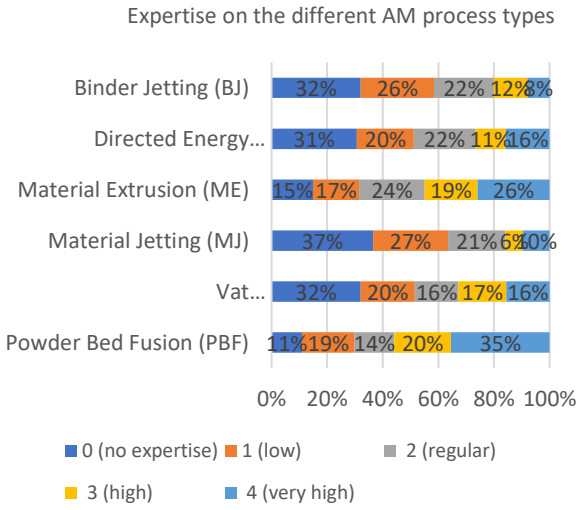


Figure 38 -Expertise in Different AM Processes

When asked about the acquired skills and know-how in the previous mentioned questions, 53% stated that they received the know-how via professional activities and 48% indicated they received training-on-the-job by an internal mentor. Another 40% answered they received training via their education.

Relevance of each category of skills from 2021 to 2022

During the survey, the industrial AM professionals were asked to prioritize the different skills categories according to their current and future activities in 2021-2022. The main conclusions for the technological, entrepreneurial, digital and green skills, are highlighted in the Table 1, below.

Relevance of AM Categories of Skills, according to Workforce Survey

Categories of Skills		Real Case (2020)	Short Term (2021-2022)	Evolution / Conclusions
Technological	MOST	• AM processes • Materials' analysis and characterization • AM applications	• AM processes • AM applications • Materials' analysis and characterization	• Consistency in terms of needs; • In general the relevance of all skills is estimated higher in 2021/2022 than in 2020 • Knowledge and Skills on Standardization loses relevance • Materials' analysis and characterization appears in 2021/2022 as most demanded
	LESS	• Design • Numerical modelling • CAPP (Computer Aided Process Planning) for AM • Robotics/Automation	• Design • Numerical modelling • CAPP (Computer Aided Process Planning) for AM • Robotics/Automation	
Entrepreneurship	MOST	• Learning through experience • Working with others	• Learning through experience • Working with others	• Motivation is maintained as most demanded • Financial and economic literacy and Mobilizing others are maintaining in both scenarios as less chosen
	LESS	• Motivation and perseverance • Creativity • Ethical and sustainable thinking • Financial and economic literacy • Mobilising others	• Vision • Spotting opportunities • Self-awareness and self-efficacy • Financial and economic literacy • Mobilising others	
Digital	MOST	• Ability to think in 3D • Digital data management (big data, statistics...)	• Ability to think in 3D • Digital data analysis (Artificial Intelligence, Machine learning...)	• There are no changes in terms of relevance in 2020/2021 • Ability to think in 3D has a high importance in both scenarios;
	LESS	• Digital data analysis (Artificial Intelligence, Machine learning...) • Coding/Programming • Cybersecurity	• Digital data management (big data, statistics...) • Coding/Programming • Cybersecurity	
Green	MOST	• Circular economy • Life Cycle Analysis (LCA) • Green awareness	• Resource efficiency management • Circular economy	• In 2021-2022 workers seem to be aware that these Green skills become more relevant
	LESS	• Resource efficiency management • Green resources • Green products	• Green resources • Green products	

Table 1 - Relevance of AM Categories of Skills

As can be seen, the most important **technological skills** in 2021-2022 will be the AM process, which is in accordance with 2020 as well. This topic is followed by AM applications, Materials analysis and design of AM parts. The least important skills seem to be Robotics, numerical modelling, sensing and CAPP (see Figure 39). Again, there were nearly no changes to 2020 noticed.

In terms of **entrepreneurial skills**, in the future learning through experience and working with others as well as vision and spotting opportunities has been rated as highly relevant (with over 50%) (see Figure 40) Again, there is no change seen to 2020.

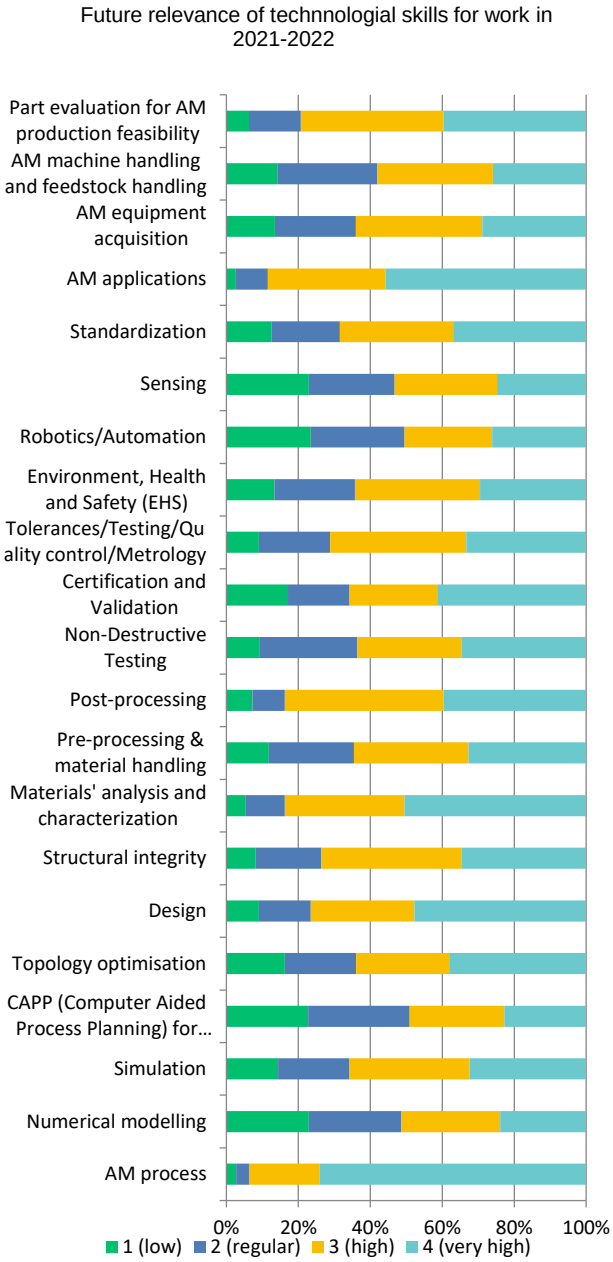


Figure 39 -Future relevance of technological skills for work

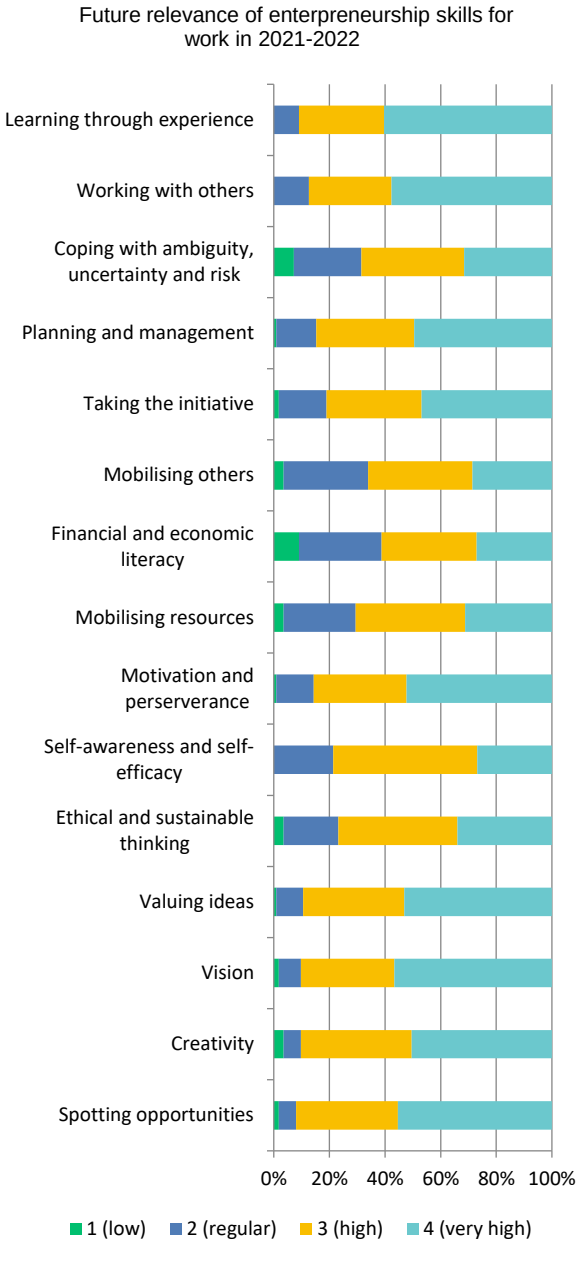


Figure 40 -Future relevance of entrepreneurial skills for work

In terms of **digital skills** (see Figure 41) the ability to think in 3D and digital data analysis (which incl. AI and ML) has been rated the highest. For the ability to think in 3D, 82% of the respondents stated that it will be highly or very highly relevant. This result is in line with the year 2020. However, a big jump can be noted in the percentage of people thinking these topics are highly relevant. For the future the relevance (percentage) of the topics is significantly higher. The relevance for **green skills** (see Figure 42) in general will be higher in the future (2021-2022) as has been rated for every topic listed. This is in line with the digital skills. Topics that have not yet reached the importance like other topics should as control of the AM process, will be considered higher in the future.

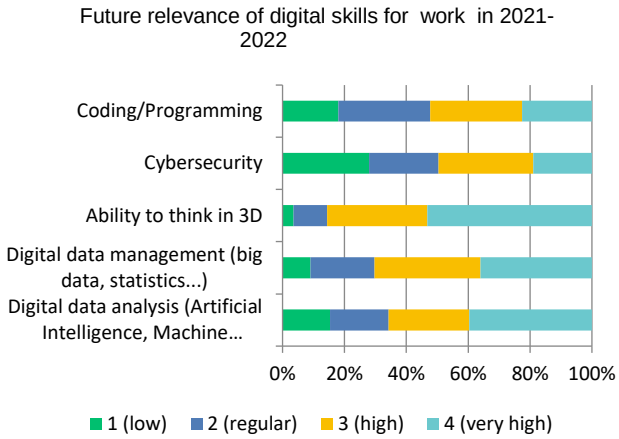


Figure 41 -Future relevance of digital skills for work

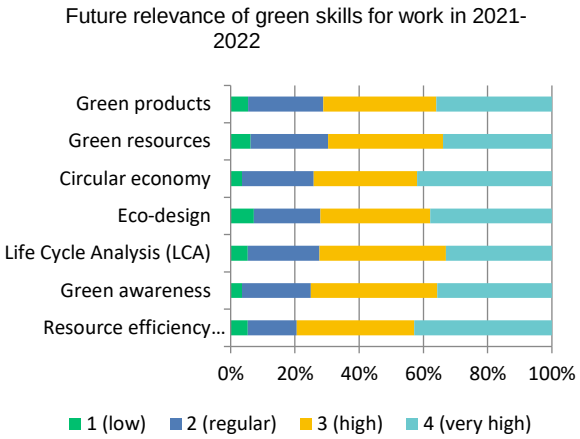


Figure 42 -Future relevance of green skills for work

In terms of **new knowledge on materials** that should be acquired by the AM workers until 2022, 60% stated that the implementation of new applications and products for all materials is important. This is closely followed by 59% stating that knowledge in the development and standardization of new materials as well as knowledge for multi-material parts (58%) will be highly relevant within the next 2 years (see Figure 43).

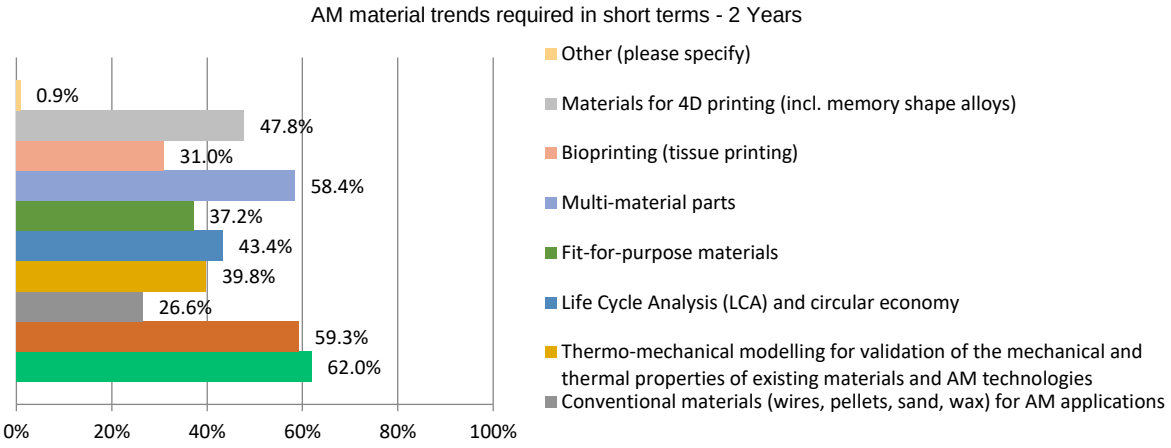


Figure 43 – Workers required knowledge on AM materials in the next 2 years

In terms of **new knowledge on AM processing** to be acquired, workers identified that AM machines for multi-materials will be become a relevant topic (58%) as well as multi-functional parts incl. parts with embedded sensors, hybrid machines and faster AM metal machines (all around 43% respectively), see Figure 44**Error! Reference source not found.**. To which regards to **new knowledge on post-processing** to be acquired in the next 2 years (see Figure 45), processing trends, new quality standards, design to minimize post-processing, improved heat treatments as well as new surface finishing and automation of support removal have been rated nearly equally important.

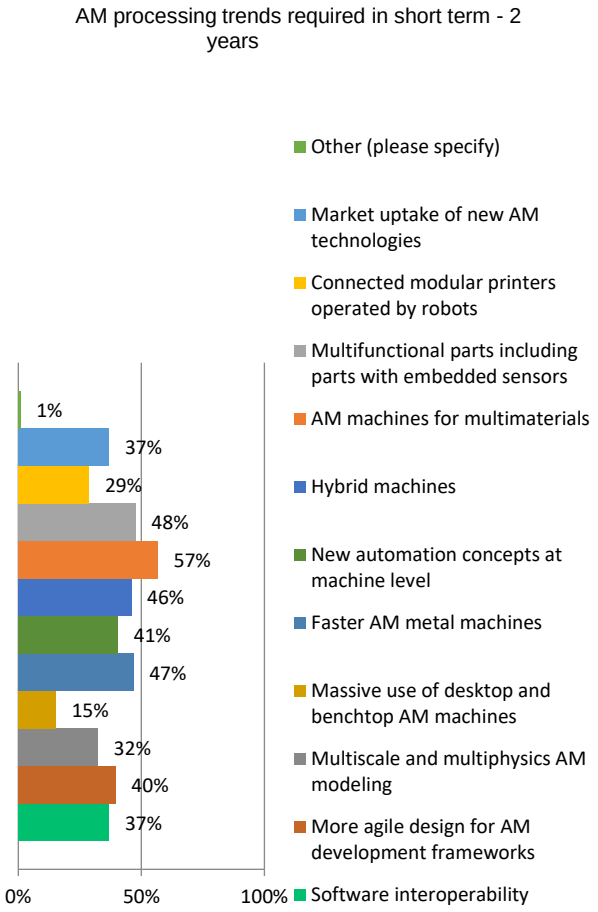


Figure 44 -Workers required knowledge on AM processing in the next 2 years

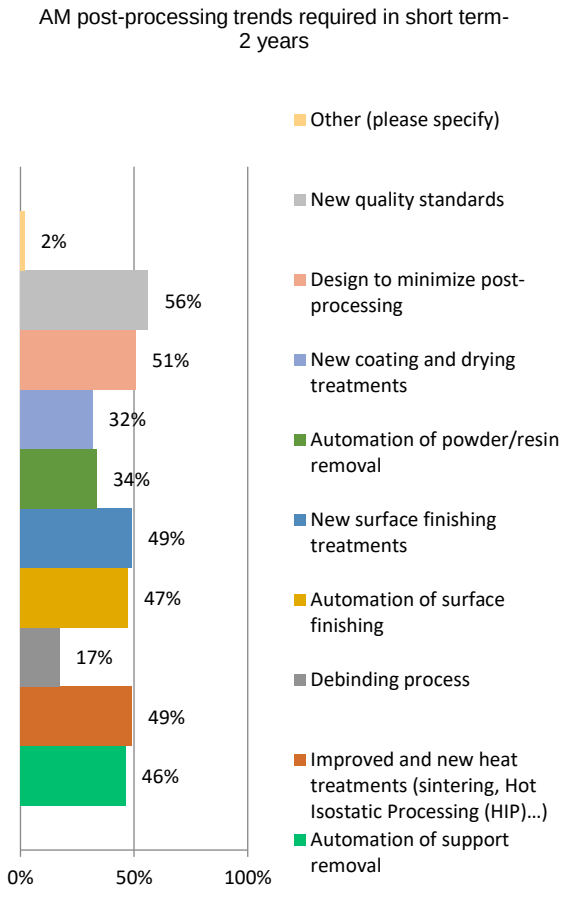


Figure 45 -Workers required knowledge on AM post processing in the next 2 years

Finally, in terms of **new knowledge** to be acquired in **ICT and quality control** in the next 2 years, improved AM process control, new inspection techniques and advanced monitoring systems have been rated the highest with AM process control accounting for nearly 60% of the answers (see Figure 46).

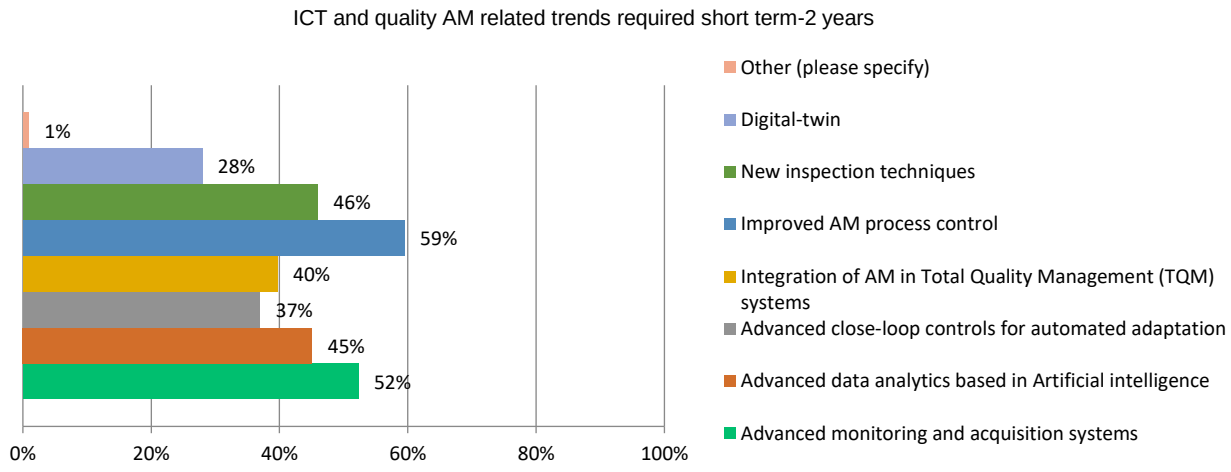


Figure 46 - ICT and quality AM related trends within the next 2 years

Relevance of learning and assessment tools

The survey included the auscultation on the most suitable learning approaches to be used in the upcoming years. According to the workers, on-the-job training is still rated the highest, followed closely by practical activities, online and short courses (see Figure 47**Error! Reference source not found.**). This is a general trend seen in AM, a lot of knowledge can be gained but also generated by using a practical approach to the topics. As AM is still relatively new, hands-on experience is desirable. The contestants preferred blended learning approaches and short/intensive modules (44%) (see Figure 48), as well as part-time learning (see Figure 49).

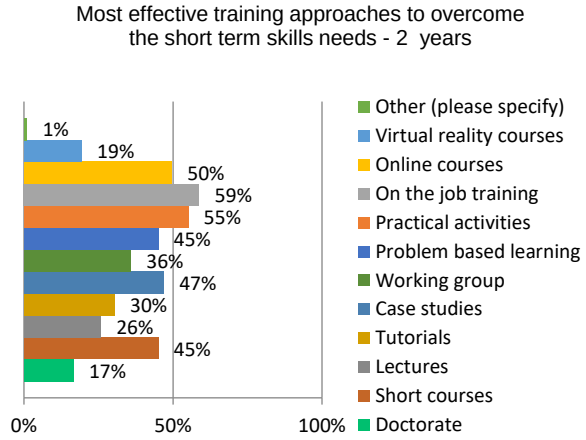


Figure 47 -Effective training approaches within the next 2 years

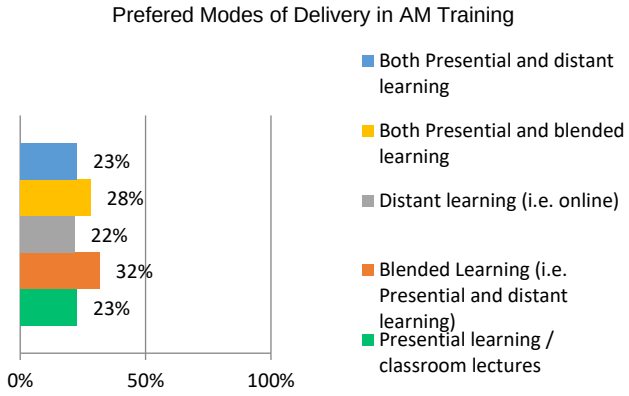


Figure 48 - Preferred modes of training delivery by AM workers

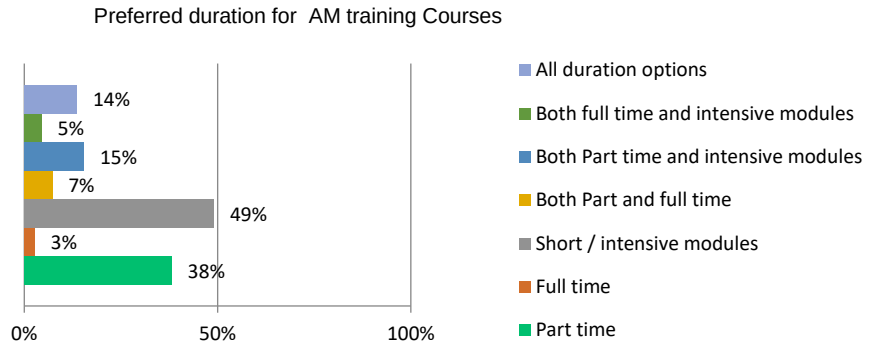


Figure 49 - Preferred training duration by AM workers

4.3 Findings on Surveys conducted with AM Industry

The survey among industrial organisation was carried out from July to November 2020, gathering a total of 56 replies.

General information and background

Out of the 56 participants, 35% belonged to a large company and 30% to an SME (see Figure 50**Error! Reference source not found.**). Turn-out was the highest from Italy – 21% of the responses. This was followed by the Netherlands (10%) and the UK (18%). 89% of the respondents responded that they were currently using AM. The majority (71%) of the participants stated that their organisation was using AM for over 5 years (see Figure 51).

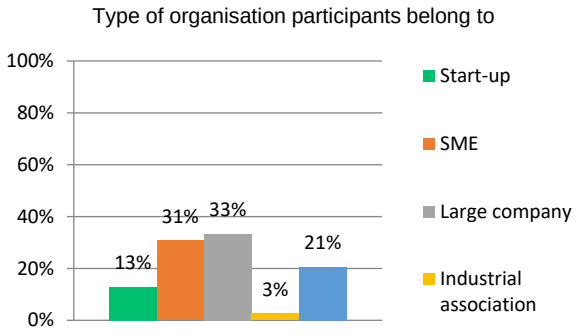


Figure 50 -Type of organisation participants are involved in

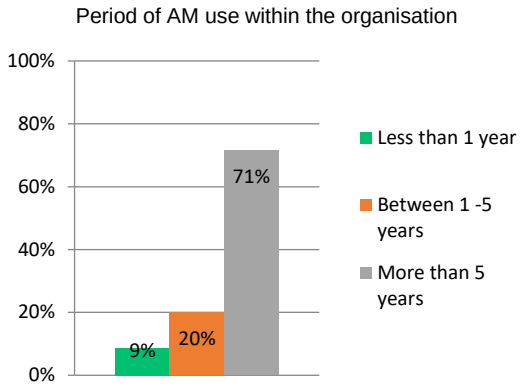


Figure 51 -Period of AM use within the organisation

The majority of the participants listed research and development as their supply chain (78%). This is followed, with a big gap, by design (30%) and OEM (24%) (see Figure 52). In terms of materials that have been mainly adopted by the companies, metal (83%) and plastic (64%) were rated the highest. Biomaterials, composites and ceramics were only been rated by 14-22% of the contestants (see Figure 53). In terms of processes, PBF (83%) and Material Extrusion (64%) were mentioned to be employed by the majority of contestants. This has been seen for the workforce as well. Sheet lamination and "other" have had the lowest responses.

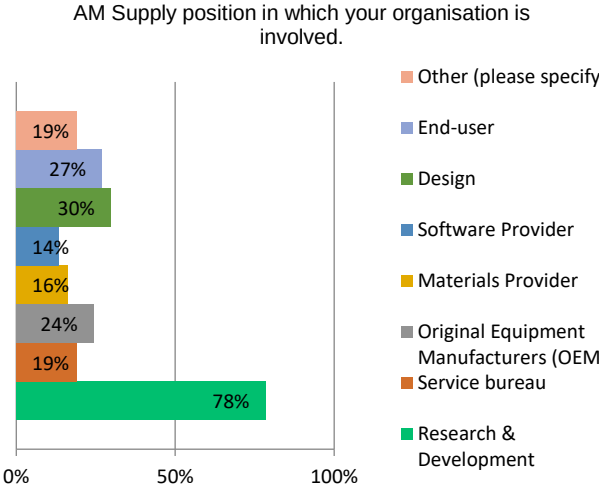


Figure 52 -AM Supply position of organisation

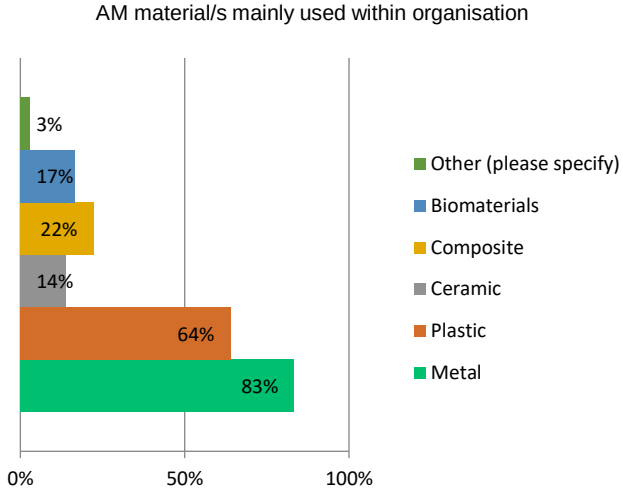


Figure 53 -AM materials mainly used by the organisation

Current relevance of each category of skills

In terms of required AM professional profiles in companies, results revealed that the process engineer, the designer and the materials engineer continue to be rated as the highest (combination of high and very high) NDT technician and Inspector seem to be less needed currently (see Figure 54) .

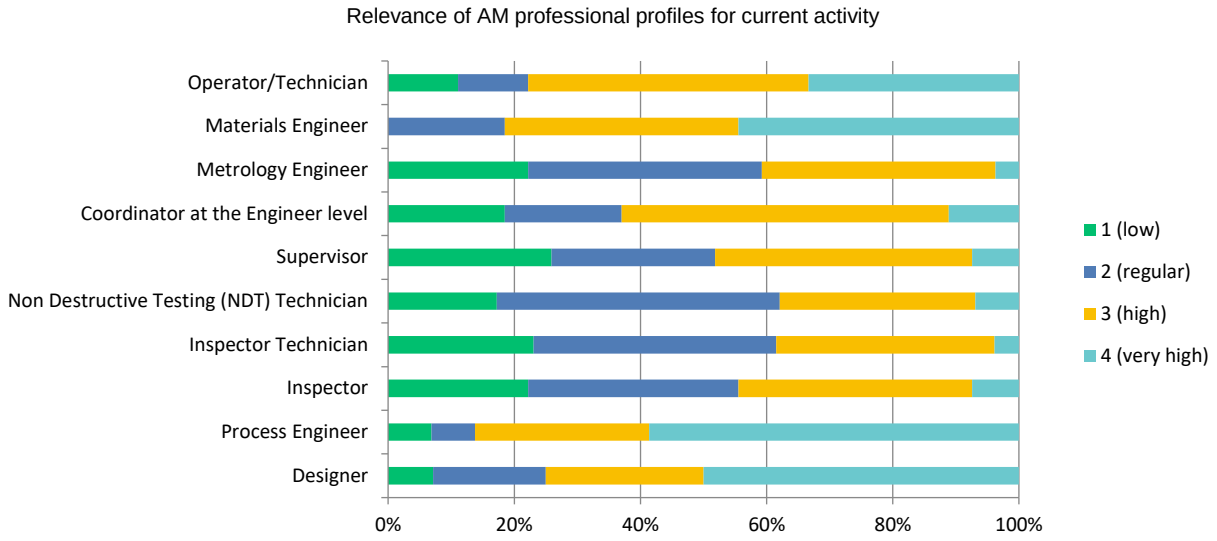


Figure 54 - Current relevance of the AM professional profiles

In the current context of COVID 19 pandemic, participants (89%) confirmed the importance of capacitating non technological professionals (see Figure 55) towards AM use, against 11%. Health professionals were mentioned as the profiles that could benefit from global training on the manufacturing process to be more aware of the potential risks encountered by the users. Additional arguments were presented to support this approach:

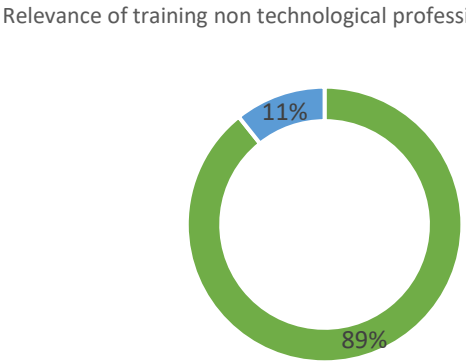


Figure 55 - Relevance of training non technological professionals towards AM

Additional arguments were presented to support this approach:

- AM business requires support from cross-functional resources. AM competency training enables better inter-departmental collaboration.
- to understand the technology and its capabilities, as well as limitations, so that these professionals also can propose innovative and feasible solutions to challenges within their sector.
- Always important, especially with focus on applications and their potential
- Due to lack of specific standards and regulations
- May speed up AM technology introduction
- Important to spread knowledge for a wider awareness of capabilities and part of industrialization, etc.
- Raise awareness of risks of AM for safety responsibilities

With regards to the question, on which technological skills are currently missing amongst the organisation staff, **post-processing, certification and validation, standards and costs have** been rated the highest (see Figure 56).

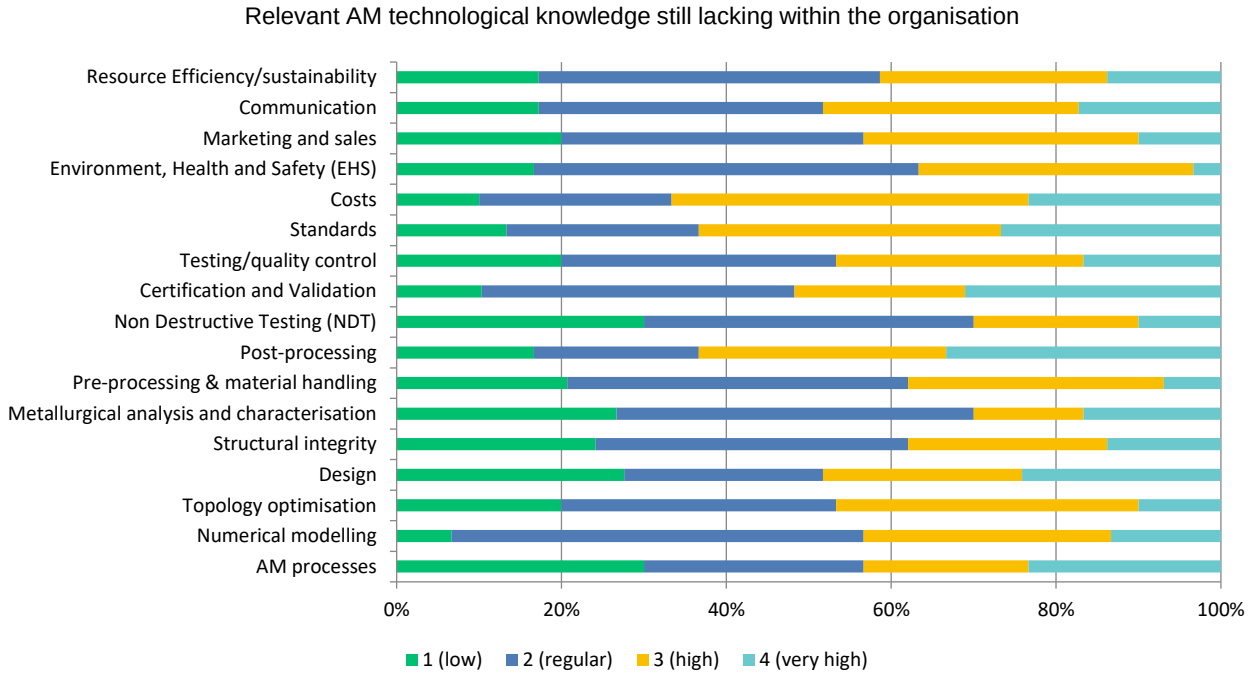


Figure 56 - Current relevance of technological skills

In terms of **entrepreneurial skills**, 87% considered it important for staff to develop skills in this topic. As can be seen in Figure 15, staff is lacking taking the initiative as well as motivation and perseverance (see Figure 57).

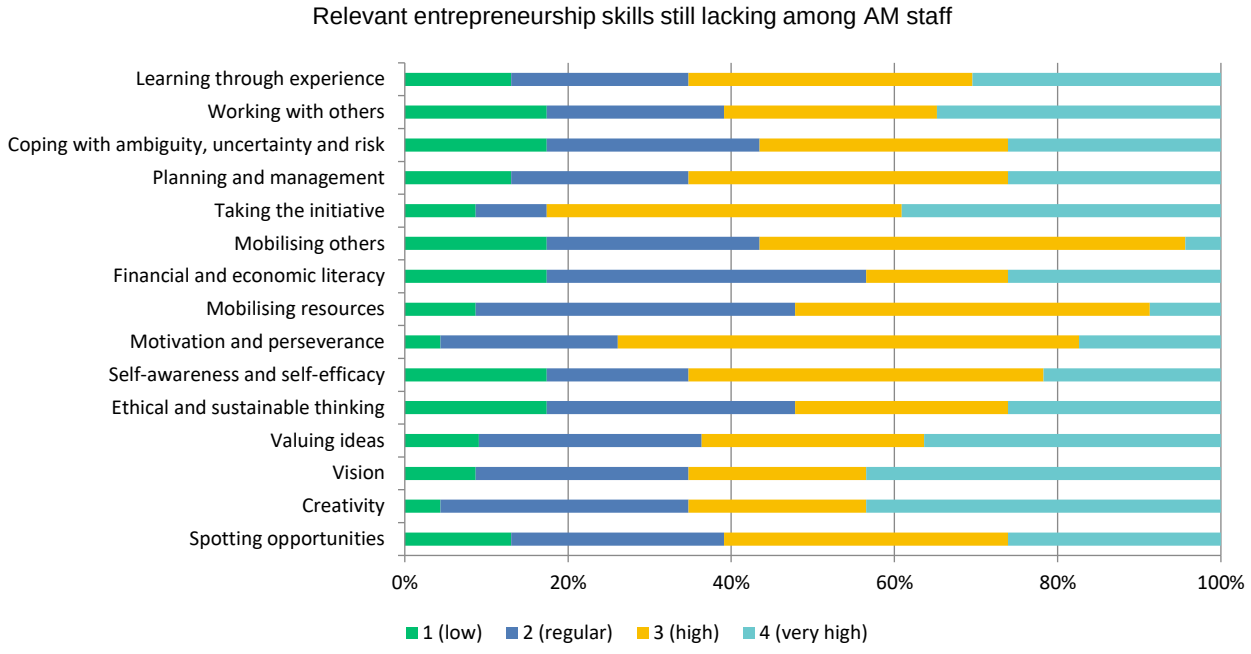


Figure 57 – Current Relevance of entrepreneurial skills

Furthermore, 96% of the contestants find it important for their staff to gain digital skills. In terms **of digital skills,** as for the workforce, the **ability to think in 3D** is rated the highest (75% high and very high). For the rest of the skills, the importance is rated equally (see Figure 58). Regarding **green skills, knowledge about the circular economy is missing**. Again, also for green skills, the percentages vary only slightly between the different topics. Green products seem equally

important as green awareness. However, 86% of the contestants wish for green skills to be developed (see **Error! Reference source not found.**Figure 59).

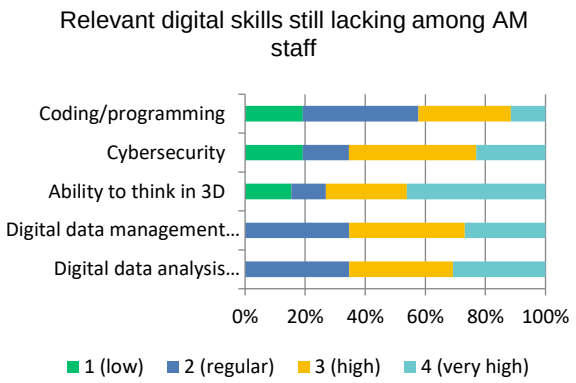


Figure 58 -Current Relevance of digital skills

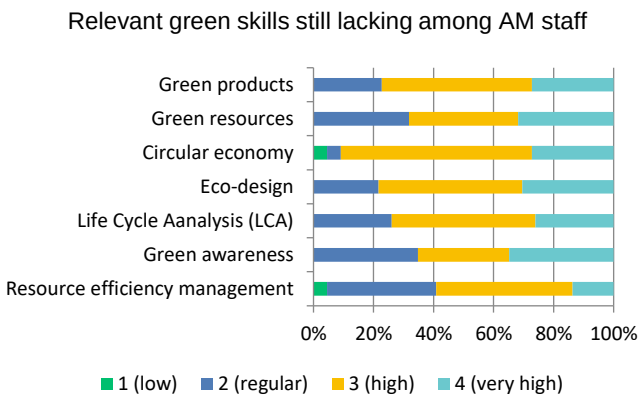


Figure 59 -Current Relevance of green skills

Future of AM:

When being asked about the future of AM in their organisation, 79% of the contestants expected an increase in AM in their company in the next 6 months. 78% rated that the number of applications would be responsible for this, whereas another 70% rated the testing of new materials and testing of new AM technologies (63%) as the main responsible (see Figure 60).

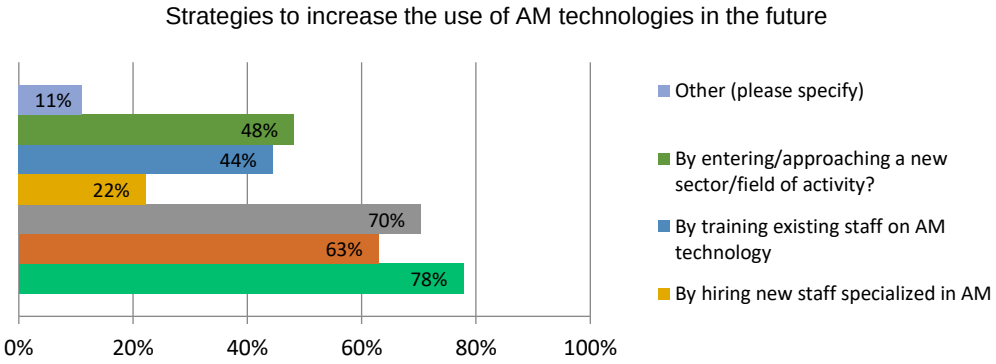


Figure 60 -Strategies to increase AM technologies use in the future

The future professional profiles needed have been listed (seeFigure 61**). R&D staff**, as well as **process and quality managers** have been listed the highest. In accordance with this, the question was asked on which knowledge would be especially important for the professionals to achieve (see Figure 62**Error! Reference source not found.**). The outcomes refer to **standards, post-processing**, **design** and the **AM process** have been rated to most important topics.

Figure 61 -Relevance of professional roles in the future

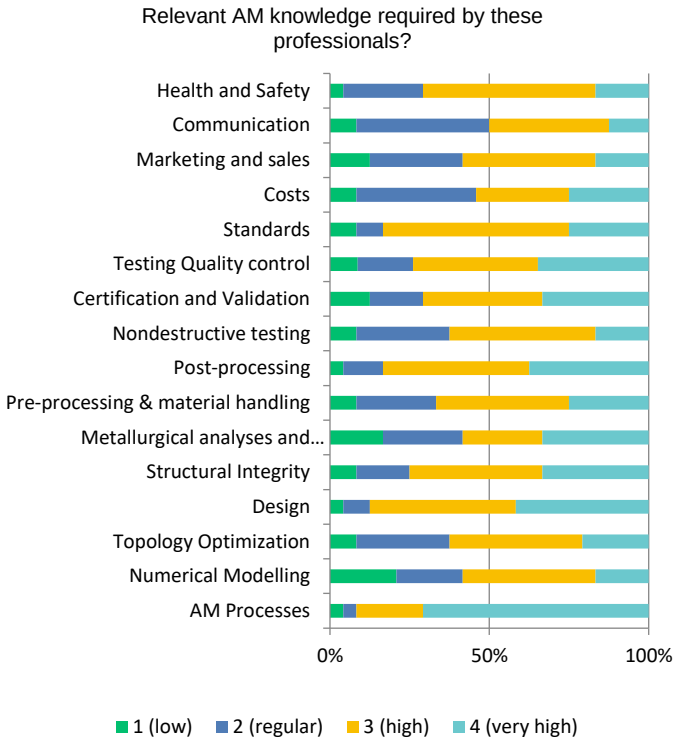


Figure 62 -Relevant AM knowledge required by professionals

4.4 2nd Workshop to Validate Skills Needs - External Workshop Results

The workshop with external stakeholders enabled to consolidate prior findings on required skills and brought new elements of reflection concerning the strategy implementation. Still, the major focus was to set the priority to address green, digital and entrepreneurial skills, that will be considered in the next stage of piloting activties.

Plenary session details

The validation workshop was conducted with a group of 19 experts belonging to industry (e.g. Technology Suppliers, Equipment Manufacturers, Companies, etc. Project partners EWF and LAK were being responsible for presenting the objectives and the motivation that brought the consortium to develop SAM project, as well as the first project results, meaning addressing the 2nd round of auscultation in 2020 on current and short-term skills needs and gaps in AM.

After a brief presentation of the participants, Adelaide Almeida, EWF, delivered the 1st presentation in which she presented SAM and the AM Skills Strategy and address its relevance for industry.
The workshop continued with the presentation of the second-year project results. Yvonne Wessarges, LAK, presented the AM skills needs and technological trends, resulting from the series of surveys with training centres and industry.

Finally, Beatriz Lopez, EWF, gave the audience some background information about the 1st AM Qualification System (IAMQS).

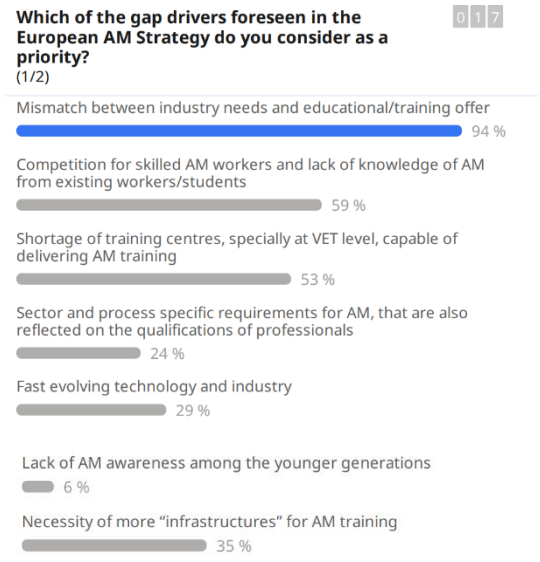
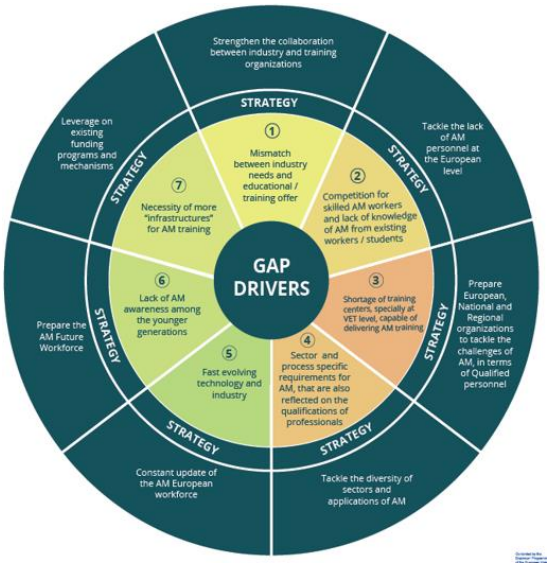
Experts' agreement on priorities

To define the trends and priorities for qualified personnel in the AM Industry, the following questions were addressed in the group discussion:

- *Which of the gap drivers foreseen in the European AM Strategy do you consider as a priority?*
- *Which of the implementing and supporting activities do you consider as a priority?*
- *Which are the emergent process in AM for the next 3 years?*
- *Which Digital Skills are a priority to be addressed for AM?*

During the hands-on, participants interacted through slido. The results achieved regarding each questions subject, are gathered and described from Table 2 to Table 7).

Table 2 – Agreement on gap drivers' priority

Which of the gap drivers foreseen in the European AM Strategy do you consider as a priority?	
	

Three main gap drivers were considered as a priority by the industrial stakeholders namely: Mismatch between industry needs and educational/training offer; Competition for skilled AM workers and lack of knowledge of AM from existing workers/students; and the Shortage of training centres, specially at VET level, capable of delivering AM training.

Incentive for training and qualification is now a priority in terms of AM, that should be promoted by the end-users.

Table 3 - Agreement on the AM strategy activities priority

Which of the implementing and supporting activities do you consider as a priority?

The experts agreed that the following **actions are urgent** to be undertaken within the **Sector Skills Strategy Roadmap:** Engage industry in the identification of skills and validation of training programmes; Engage industry, academia, training organizations and authorities in projects for collaborative implementation of AM training, supported by a Quality Assurance System; Implement European Qualifications that are recognised by different sectors supported by a Quality Assurance System.

The lack of understanding and awareness on the importance of being qualified was also mentioned. The participants agreed that training requirements should came from the end users in order to incentive people for being qualified. The work that has been done on standards can also have an important role here.

Finally, the **importance of having a Quality Assurance System underpinning training** has been highlighted due to the difficulty in assure the same training level in different countries, particularly at this stage in which the level of maturity of AM still varies widely among European countries.

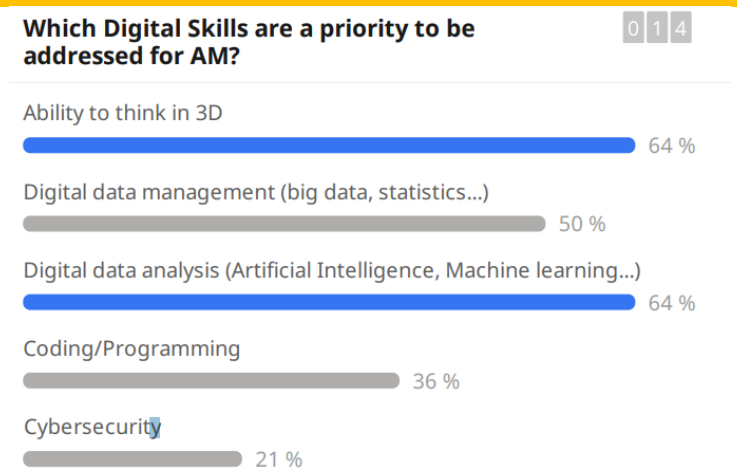
Table 4 - Agreement on the most used AM process in 3 years

Which of other processes, apart from PBF-LB do you think will have a great impact in AM in the next 3 years?

Although experts confirmed that PBF-LB continues the most requested process, however they agreed that in the last year an increased demand for **DED processes**, mostly in terms of **facilities certification** was noted. This shift in the processes is mainly related with the type of industries that are adopting AM nowadays, particularly the **aerospace sector.**

Table 5 - Agreement on digital skills priorities

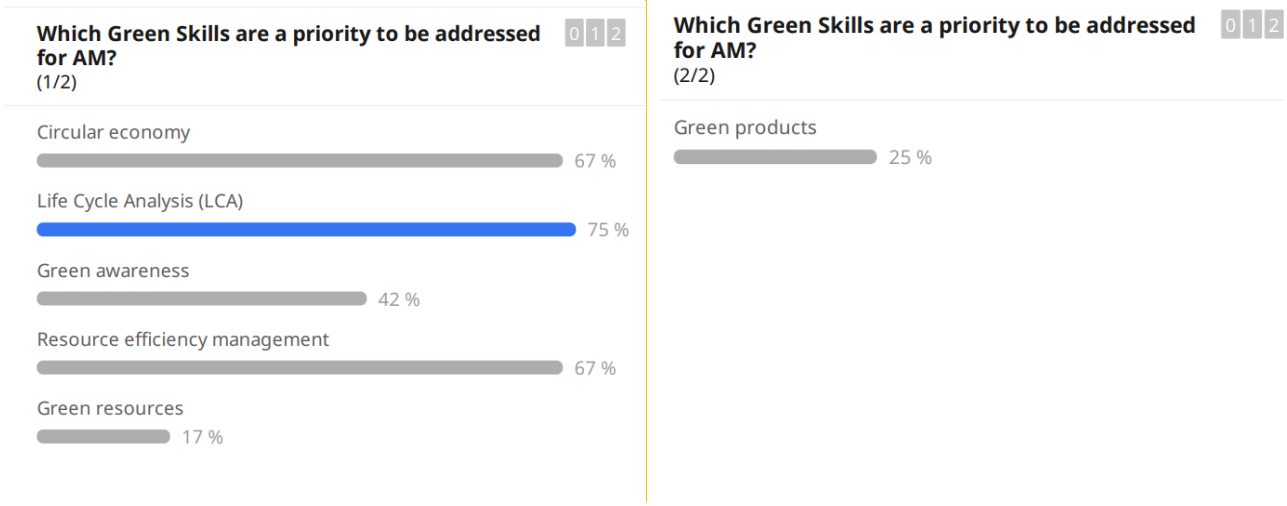
Which digital skills are priority to be addressed for AM?



Experts agreed that the **Ability to think in 3D, Digital data analysis** (Artificial Intelligence, Machine learning...), followed by **Digital data management** (big data, statistics...) are the priorities in terms of **digital skills** capacitation.

Table 6 - Agreement on green skills priorities

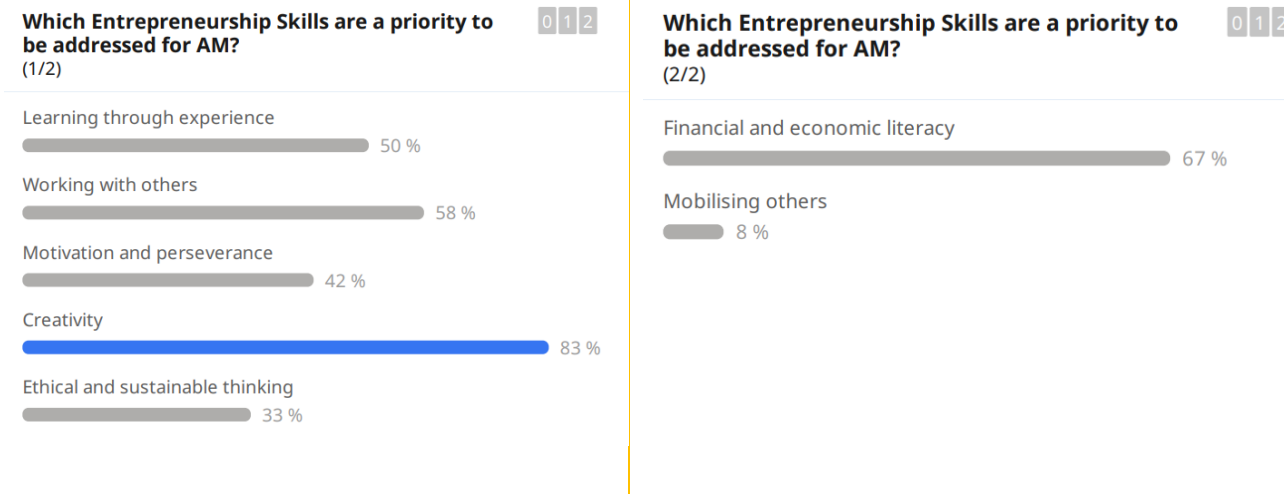
Which green skills are priority to be addressed for AM?



In terms of **Green Skills: Life Cycle Analysis** (LCA), **Circular economy** and **Resource efficiency management** are the most important ones to be address within AM workers training.

Table 7 - Agreement on entrepreneurial skills priorities

Which entrepreneurial skills are priority to be addressed for AM?



Finally, **Creativity, Financial and economic literacy** and **working with others** were validated by the experts as being the most relevant **Entrepreneurship Skills** to be addressed.

4.5 Data on AM Polymers Skills Needs - Interview Results

A total of six interviews were conducted with AM experts in the field of Polymers. Both a quantitative and qualitative approach was used to analyse the interviews' results.
Findings were compiled within this chapter and described into two main clusters: General information / background and AM Polymers skills needs.

Background information

Interview participants were in their majority representatives from the AM Industry (four out of six) followed by one Academia representative and one Technology Centre representative, from three European countries (e.g. Spain, Greece and Spain). **Experts' fields of ex**pertise and background is detailed in Table 8.

Table 8 - AM Polymers Experts Expertise and Background

Organsiation Type	Expertise on AM and position
Academia / University	**Current position**: Professor for Composite Manufacturing in *Mondragon University* **Expertise**: Enthusiastic researcher using heterodox approaches to liquid composite moulding technologies, especially RTM and pulltrusion. Generating basic knowledge of impact-resistant composite materials for road transport, civil engineering and sport/leisure applications is within the scope of his career. PhD in Industrial engineering and a degree in Materials Science
Company /Industry	**Current position** Lead consultant for AM **Expertise**: Business development/project management expert with more than years' experience. Executive MBA, driving initiatives that involve innovative technologies, especially Additive Manufacturing, while creating added value for the company's product and services.
Company /Industry	**Current position:** Account Manager in the 3D printing **Expertise**: With seven years' experience with the end-to-end management of B2B sales in the 3d printing industry. Founder and CEO at "3doers", a 3dprinting B2B network-based start-up.
Company /Industry	**Current position** R&D manager at *Filoalfa* **Expertise**: With seven years' experience in production of extruded filament for 3D printing.
Research & Technology Centre	**Current position** AM and prototyping responsible **Expertise**: Head of additive manufacturing area. Senior Mechatronics Engineer: Degree in Engineering . Expert in design of products and tools, specifically for AM parts and tools. Sixteen 16 years of experience in AM processes. Participation in more than 50 research projects related to prototyping, AM and in the development of 3D printing technologies.
Company /Industry	**Current position** : Project manager at *Sculpteo* **Expertise**:Iindustrial design for 3D printing as well as an application engineer for Fabpilot, Sculpteo's AM production management software. Engineering degree.

Polymers AM skills needs

Regarding the profiles most demanded by industry (see Figure 63), **AM Designer for polymers** was the one most indicated by the experts, followed by **AM Operator for polymers.** One comment associated to these results was that even if the Operator profile is the first request currently, the Designer profile is the one that in a long term can add more value. "*The profile of AM designer it is mostly demanded because the designer can offer an added value service to the*

customer for (re)designing a part. It is really important for a company to have fast and efficient designers because it is difficult for a small company for example to hire someone and train them on materials and how the technologies are working. It is preferred to find someone with all the abilities."

Additionally, there was one expert indicating an additional profile: **Salesperson/Application Engineer** because "*to sell a product, it is important to know the AM technology and what is feasible, in order to clarify with the customer which opportunities are feasible and which are not.*"

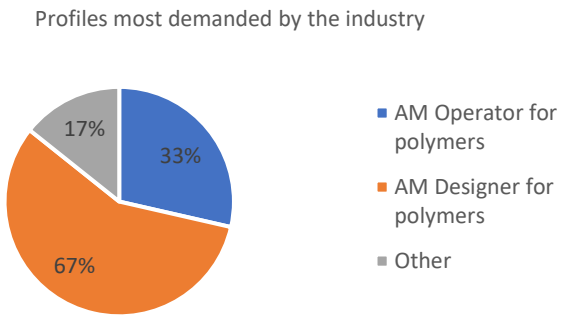


Figure 63 - Polymers AM demanded profiles

As to the most relevant processes applied to polymers in AM at industrial level, **Powder-Bed-Fusion** appears first, immediately followed by **Material Extrusion** (see Figure 64**)**. Vat Photopolymerization and Material Jetting were mentioned once, each. One comment left by an expert elaborates a little bit more on why PBF is see as the most relevant process: "The most relevant process applied to polymers in AM at an industrial level is PBF because it can offer better opportunities. AM technologies are recently going to the industry level, which is leading to the fact that we need to create parts in high quantities and in high-speed levels, and these are possible mainly with PBF technology."

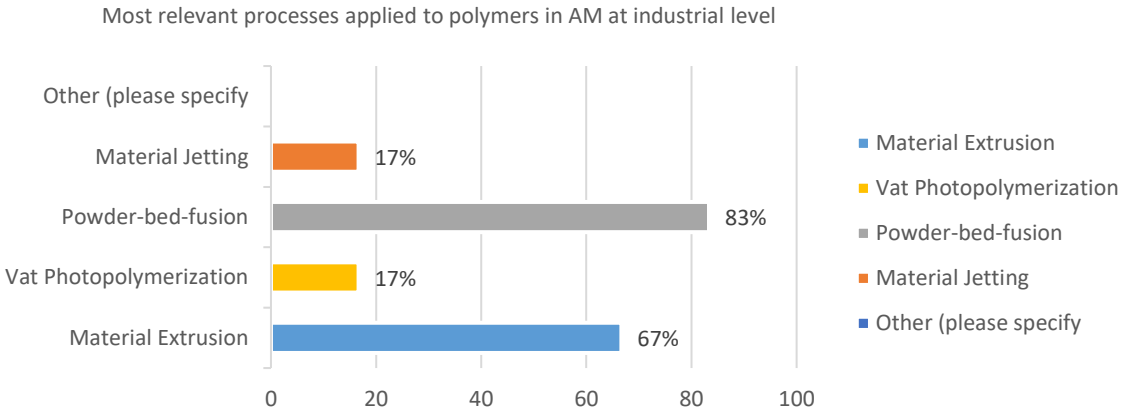


Figure 64 - Applied processes to Polymers

As to the need for having different profiles categories for the different processes in AM, opinions divide, as made clear by the answers of the experts mirrored (see Figure 65). This may be explained by the diversity found in the type of existing companies and respective needs: "*In case a company uses all the AM technologies to create parts, the designer should know all the AM technologies, to be able to find the best solution to a customer problem. On the other hand, in case a company uses only one AM technology – for example, SLS - the designer will have to manage mainly problems regarding that technology at a rate of 95%.". Another comment made by an expert was that "The operator in polymer AM can be easily trained on different systems, but the designer has more to learn, especially if you take in consideration material properties".*

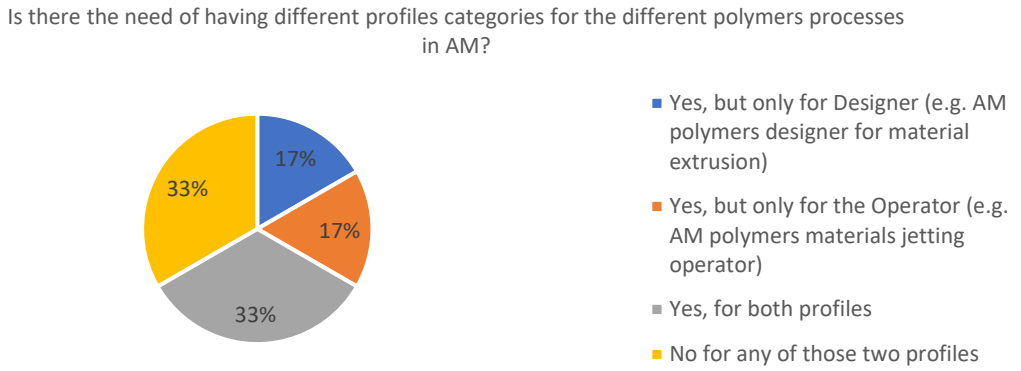


Figure 65 - Need for specialization by process in Polymers Profiles

Specific knowledge and skills needed by an AM designer (with focus on polymers), compared to a traditional designer:

- Know the whole process of fabrication and the materials
- Be able to execute simulations on the created part
- Consider the whole part life cycle in one process step
- Have sufficient AM knowledge to be able to make specific designs to be manufactured by AM, as in AM technologies the costs with material is directly related to the final volume of the piece (the lower the volume of the piece, usually the lower the material costs and, therefore, the more economically competitive piece)
- Knowledge of 3D printing polymers process, with its pros and cons
- Different limits - not on the geometry, but on the possible deformations during the process or the mechanical properties that the new geometries can afford.
- Post-Processing
- Flexibility and Customization
- Material properties linked to designs
- Parts orientation
- How to remove supports
- Possibility to avoid the assembly of more parts, producing a single one since the first step.
- Think about the purpose of the part, what tensions it will work with, which requirements of surface or accuracy
- Design tools for AM
- Generative design and topology optimization

Which are the main tasks and responsibilities of AM Designer for Polymer? What is different /specific in terms of responsibilities and task comparing to a traditional designer?

- In AM, there are some design rules for each technology but the influence of the designer experience in the field is key.
- Specific knowledge on the AM production systems. Also, in a production flow, you must consider cost per part linked to the result that you must achieve, or if it will be possible to produce the product in a large volume, e.g. if you can prototype a new geometry just with a Photopolymerization, then how can you produce it? The Jetting technology is adding value on this but so far is still a matter of thousands of parts and not millions. So, at least for some year, the designer must take in consideration the whole system in which he is working.
- Design parts that need no supports to be produced
- Consider the anisotropic behaviour of the printed parts

- The manufacturing costs and functionalities of a part are highly dependent on the manufacturing technology used, and it is the designer duty to optimize the designs so that the full benefits of these technologies are obtained, and the weaknesses are minimized.
- As a designer, you test your part, print the part, test how relevant is the solution you have found and how resistant. As a designer, you need to be able to access the used technology and to test.
- Define the expectations of the customer, clarify to him what is possible to create, define the limits and the specifications of the product.
- Defining the specifications to match AM technologies.
- Convincing others about the new design rules.

Specific knowledge and skills are required for an AM Designer for Polymers regarding post-processing:

- Technical post-process because as a designer you need to know how the part will be printed, the size of the used machine in order to design a part with the appropriate size.
- At an aesthetic level, to know when the part will be polished and how, because when you design a part you need to know which post-processed will be used, in order to avoid any mistakes (for example, there can be some kind of discrepancies and the polish may stack bubbles on the part).
- There are two basic types of post-processing in AM: those that affect the mechanical functionality of the parts, and those that affect the surface finishing. Knowing which techniques can be applied to each technology to achieve certain surface and aesthetic finishes is important to be able to apply the most appropriate technologies to each type of part, from the functional and aesthetic point of view.
- It's not just a matter of surface finishing, but also chemical properties, if you need to paint or do a coating. Polymers are more complex than metals in this, and we often have several issues with our customers.
- Influence of design in post processing, sandblasting manual and automatic, tumbling, painting, "heat treatment" for some polymers, new smoothing technologies, and gluing components.

Specific knowledge and skills required for an AM Designer for Polymers regarding simulation analysis and execution:

- Mechanical simulation, Optimization, build simulation - Nesting, part consolidation, open minded to try new mechanism (life hinges, etc.) and organic designs.
- Deep knowledge of the process that will be used to produce the parts in order to apply the correct parameters during the simulation and production process.
- Know how each specific technology works in order to be able to pose the problem correctly. Many of these AM technologies cause the resulting material to have neither homogeneous nor isotropic behaviour, which has a very important influence on the workability of the parts. On the other hand, the degree of anisotropy depends very much on the specific technology in question, so the problem must be approached in different ways in order to obtain representative results.
- Know how the different technologies work in order to be able to adequately approach the analyses
- Topological optimization techniques
- Simulation aspects linked to the part and its properties
- Integrated design platforms (CAD/CAE/CAM), digital design chain

4.6 Findings on the survey conducted with recruitment agencies

The survey for recruitment agencies was open from the 15th of March to the 20th of April 2021, gathering a total of 16 responses. Only recruitment agencies working with companies or industries in the field of AM/3D Printing in the partners countries, were invited to participate. The goal of the survey was to characterize the job opportunities and define the employability data in the AM labour market.

General information and background

The role of the participant in the study within their recruitment agencies/organizations were: Permanent Recruitment, External Relations, Account Permanent, Director of Services, Director, Recruiting Manager, Chief Operations Officer, Manager, HR Senior Consultant, Director/Founder.

In terms of coverage, the majority of the responses came from Ireland and Italy (37%), followed by the United Kingdom (12%), Belgium and Portugal (6%).

According to In line with the previous answers, there is also a significant interest (78% of the responses were Yes in opposition to 14% No) in posting job offers in a dedicated platform for AM/3D Printing. Leaving 7% to Other, corresponding to "Not at this time" and 2 participants who chose not to answer (see Figure 68).

Figure 66, there is balance when it comes to recruitment agencies/organisations scope, when it comes to work specifically with AM/3D Printing companies/industries with AM specific needs. There is also a small percentage of 6% that answered Other corresponding to: "It is one area we focus on" and 1 participant who chose not to answer.

The majority (71%) of the participants confirmed their interest in accessing a platform where they could search for AM/3D Printing professionals available (see Figure 67), in opposition to 21% of the participants which did not.

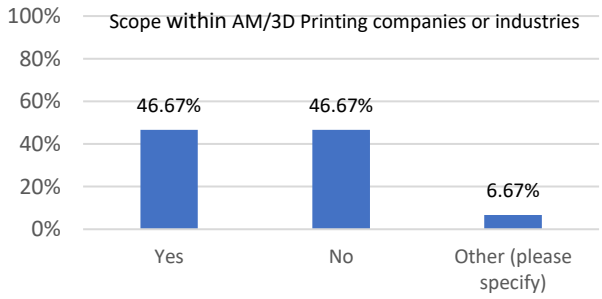


Figure 66 -Recruitment Agencies AM/3D Printing Scope

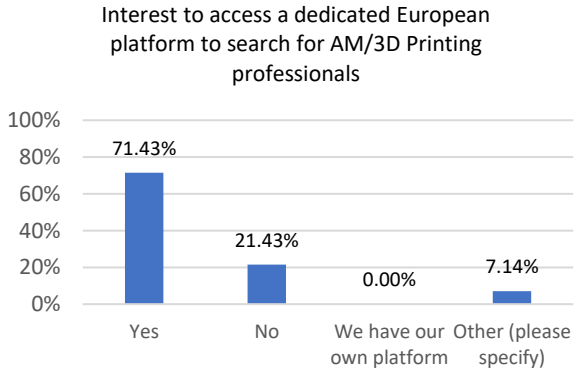


Figure 67 -Interest in accessing a European platform for AM/3D Printing professionals

In line with the previous answers, there is also a significant interest (78% of the responses were Yes in opposition to 14% No) in posting job offers in a dedicated platform for AM/3D Printing. Leaving 7% to Other, corresponding to "Not at this time" and 2 participants who chose not to answer (see Figure 68).

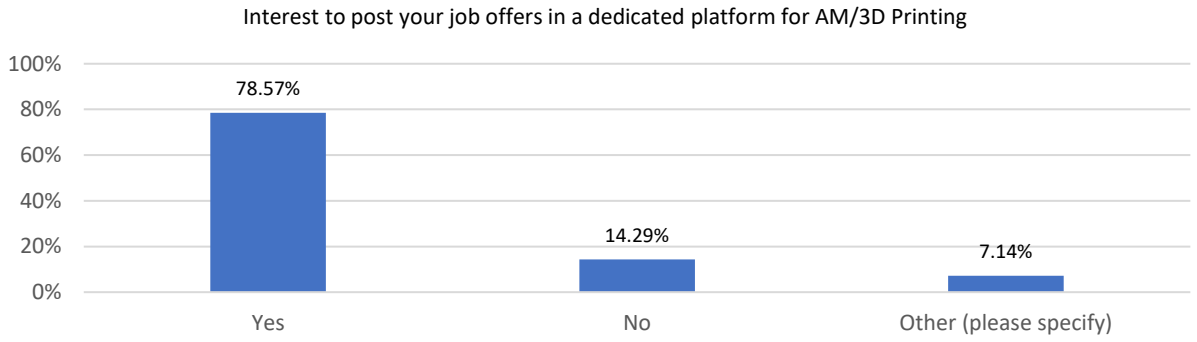


Figure 68 Interest in posting job offers in a European platform for AM/3D Printing professionals

In terms of AM recruitment platform, participants were questioned about the ideal features they would expect to see in such a platform. The contributions were the following:

- "Adapted to current technology"
- "The opportunity to get in touch with professionals in the sector"
- "Quality"
- "Linked to social and professional media & supported by a marketing campaign",
- "An ability to search on the professionals that wish to register to such a platform and post jobs would be very useful. Search parameter design is critical to the platform and needs careful consideration",
- "Job posting, network candidates, company network, forum"
- "If we could have a platform that allows engagement between an agency and job seekers - a site that would allow us to provide key selling information on roles available and companies offering positions. If we could also build talent pools so when positions arise, we have a dedicated platform to engage with active and passive candidates"
- "Easy to search skills profiles and simple means by which to contact professionals".

AM job hiring demand

In terms of job hiring **demand by occupation in Metal AM / 3D,** participants considered the rate level as *High* for **Metal Process Engineer**, **Materials Engineer**, **Designer and Operator/Technician.** As for, Metrology Engineer, Coordinator at the Engineer level, Supervisor, Inspector, Non-Destructive Technician and Inspector Technician the level is considered to be Regular (see Figure 69 **Error! Reference source not found.**). However, it is possible to identify differences in the demand for the same professional profiles for Polymer. Designer and Process Engineer maintains the same rate level of job/hiring demand in Polymer AM/3D Printing, as High, just like for Metal. But there is a slight decrease on demand in

Polymer compared to Metal when it comes to Materials Engineer and Operator/Technician since it is considered to be Regular (see Figure 70).

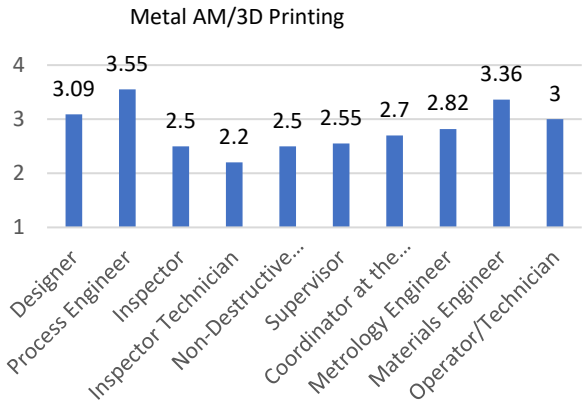


Figure 69 -Level of hiring demand for Metal AM Printing professionals

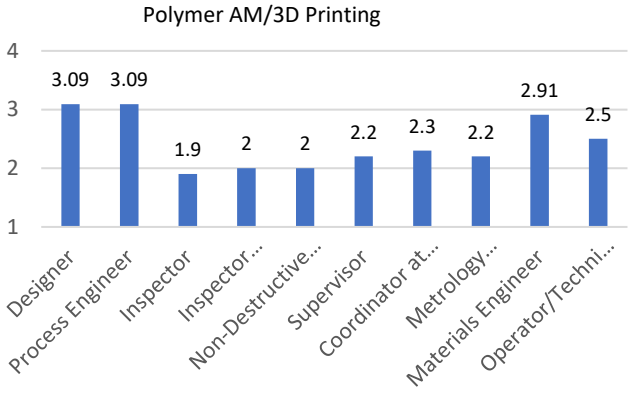


Figure 70 -Level of hiring demand for Polymer AM Printing professional

So, it can be concluded that there is **slight decrease on demand of the AM polymer occupations for Materials Engineer and Operators / Technicians.**

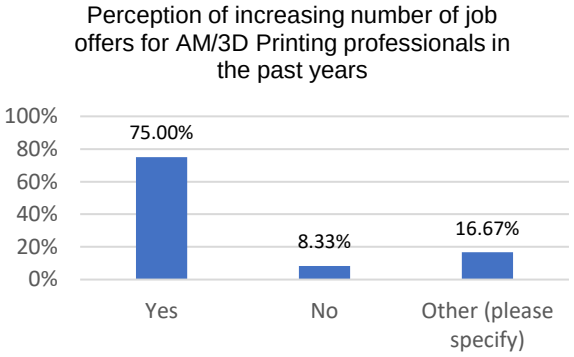


Figure 71 -Perception of the growth of job offers for AM/3D Printing in the past

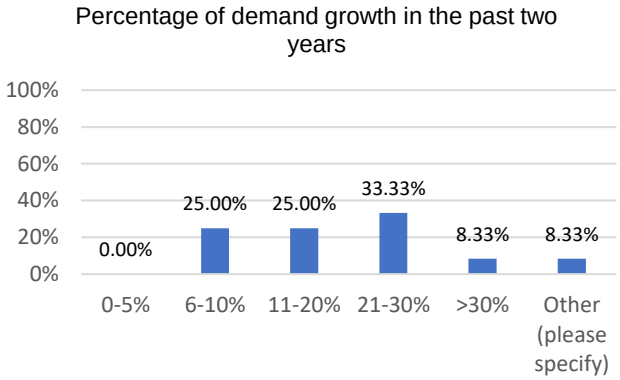


Figure 72 -Percentage of the growth in the past two years

The majority of the participants agreed that there is an increased job offers for AM/3D Printing professionals (75% answered *Yes* and 8% *No*) as seen in**Error! Reference source not found.** Figure 71. While they estimate that this **demand for AM professional has grown 21-30 %** according to the majority of recruitment agencies since 2019 (see Figure 72).

In terms of **sectors,** where the AM Professionals are mostly required, they refer to the **automotive** sector as the highest in demand for AM profiles, followed by **Aerospace** (63%), Industrial Equipment and Tooling (36%), Health, Energy, Construction (27%), *Other* – Medical Devices, Pharma Chem and Prosthetics (27%), Consumer Goods (9%) and Defence (9%).

5. Results Comparison

This section contains a comparison between findings from the workers and company's needs, as well as the analysis on how skills need evolved from 2019. In addition, the cross-check of findings on the AM skills demand, job offers and training offers was undertaken in this chapter. Cross-checking is a valuable validation technique which enables to determine the consistency of the results achieved.

5.1 Workers vs Companies surveys results

Comparing the **current skills needs** identified by the AM Workers (e.g. process engineer, operator/technician and the ones identified by the AM company managers, it is possible to identify **some divergence** regarding the evaluation of technological skills needs.

For instance, the companies expressed that their workers are still lacking knowledge on **post-processing, certification and validation, standards and costs,** while workers still continue to consider that AM processes, Materials' analysis and characterization, AM applications and Design as the most relevant domains on their activity.

Moreover, the AM workers has revealed that the current workers have less knowledge on certain materials such ceramics and biomaterials and lower expertise on end of life and modelling /simulation.

5.2 Evolution of industry needs from 2019 to 2022

In terms of required AM professional profiles in companies, it was possible to conclude that **process engineers, designers and the materials engineers** continue to be the most demanded profiles from 2019 to 2020.

Also, there **was no significative changes** concerning the required technological skills-set. The most important technological skills in 2021-2022 will continue to be **AM process**, which is in accordance with 2020 findings. This topic is followed by AM applications, Materials analysis and design of AM parts. As a prediction of most required skills in the future, **Standardization** will loss relevance while **Materials' analysis and characterization** are appearing in 2021/2022 as most demanded.

In terms of **future training needs workers identified the importance of acquiring knowledge onwards the following trend until 2022:**

- **new knowledge on materials** namely towards the implementation of new applications and products for all materials; related to the development and standardization of new materials; multi-material parts;
- **new knowledge on AM processing** namely about AM machines for multi-materials; multi-functional parts incl. Parts with embedded sensors, hybrid machines and faster AM metal machines
- **new knowledge on post-processing** namely processing trends, new quality standards, design to minimize post-processing, improved heat treatments as well as new surface finishing and automation of support removal;
- **new knowledge** to be acquired in **ICT and quality control** related to improved AM process control, new inspection techniques and advanced monitoring systems.

Finally, the detailed analysis on the different categories of skills demand by workers (see Table 1), also reveals **consistency in the skills evaluation, with green and digital skills** (see **Error! Reference source not found.**), gaining generally higher relevance in the future (2021-2022).

Based on these facts, and to align with Standardization Bodies procedures for the review of standards, the timeframe of the scenarios (and future implementation of the forecast) foreseen in sector skills strategy will be the following:

- **Scenario 1**: Real case, to addressed in less than 1 year.
- **Scenario 2:** Short-term, to be addressed in less than 3 years.
- **Scenario 3:** Foresight scenarios, to be addressed in 10 years.

5.3 Training, Industry and Agencies Surveys Results

The AM training surveys confirmed, from the point of view of the training providers, the existing alignment between workers and companies requests in terms of training. This means that current AM courses on technological topics are market driven, which is also reflected in ISO and ASTM Qualification of Personnel Standards priorities, as both workers and companies have demand for knowledge towards AM processes Design (CAD Modelling) and AM applications.

Still looking at the detailed alignment between the training offer and industry needs some mismatches can be found (see Table 9), where it is possible to conclude that **additional training programmes** are urgent focused on Post-processing, Certification and validation, Standards and costs, Financial and economic literacy, Digital data analysis and Digital data management. Still, in terms of required professional profiles, their seems to be an alignment between the EQF level targeted by training and the profiles that are recruited.

Table 9 - Alignment between training offer and AM industry/labour market needs

*Caption: **Alignment** /**Mismatch***

Alignment between training offer and AM industry/labour market needs		
Skills categories addressed in training *Reported by education providers*	**Industry needs in terms of profiles and skills** *Reported by **workers, companies and AM experts***	**Industry needs in terms of profiles and skills** *Reported by recruitment agencies*
TOP (2) AM Training levels Higher qualification levels assigned to the level of the Bachelor's (EQF 7) or master's degree (EQF6)	**Required** Profiles Process engineer, the designer and the materials engineer Upskilling of **R&D staff**, as well as **process and quality managers**	**Hiring job demand** for Metal Process Engineer, Materials Engineer, Designer and Operator/Technician
TOP (3) Sectors targeted by AM training industrial equipment and tooling sector (68%), followed by Automotive (59%) and Aerospace (50%)	N.A	**Recruiting sectors** Automotive and Aerospace
Top (3) Technological Skills that AM courses cover AM processes and AM application with a rate of 85%. Lacking training on Certification and Validation (18%) and Testing and Quality control (35%)	Required skills • AM processes • Materials' analysis and characterization • AM applications • Design • Post-processing • Certification and validation • Standards and costs	N.A
Top (3) Entrepreneurship Skills that AM courses cover • Creativity • Working with others • Learning through experience **Lacking training on** Mobilizing resources (6%), financial and economic literacy (below 10%)	Experts confirmed the priority by importance order: • Creativity • Financial and economic literacy • Working with others	N.A
Top (3) Digital Skills that AM courses cover • Cybersecurity • Ability to think in 3D • Course does not address any specific digital skills	Experts confirmed the priority by importance order: • Ability to think in 3D • Digital data analysis • Digital data management	N.A

Alignment between training offer and AM industry/labour market needs		
Skills categories addressed in training *Reported by education providers*	**Industry needs in terms of profiles and skills** *Reported by **workers, companies and AM experts***	**Industry needs in terms of profiles and skills** *Reported by recruitment agencies*
Lacking training Coding and programming/**Digital data analysis/Digital Data management are mentioned** (16%)		
Top (3) Green Skills that AM courses cover • Eco-design • Circular economy • Life cycle analysis (LCA) **Lacking training on** Green resources (5%); green products (6%)	Experts confirmed the priority by importance order: **Life Cycle Analysis (LCA)** **Circular economy** **Resource efficiency management**	N.A

To what concerns the alignment between the learning approaches and workers interest towards training, there are misalignments concerning the courses format and applied tools, as results showed that **Lectures** generally were the most common approach in training for the different categories of skills, while workers prefer on-job training and practical activities (see Table 10).

Still, it was observed that combined learning approaches were used for all categories, for instance **case studies are used as alternatives for** Technological and Entrepreneurial skills, while p**ractical activities** in Laboratory received a high rate of 75% for Technological skills.

Table 10 - Alignment between learning approaches and AM industry/labour market needs

*Caption: **Alignment** /**Mismatch***

Alignment between learning approaches and AM industry/labour market needs	
Learning practices *Reported by education providers*	**Industry and workers preferences** *Reported by workers*
Most common mode of delivery Presential Learning / classroom lectures (98%)	Preferable approach to learning **On-the-job training and practical activities**
Most common duration Short-term courses on specific AM aspects Both short- and long-term courses.	Preferable mode of delivery and duration **Blended learning** **Short courses** **Part time learning**

6. Conclusions

The aim of this report was to document the priorities in terms of AM skills development considering the inputs from combined sources operating in different industrial sectors. The report constitutes the baseline to identify and anticipate skills gaps and demands of the AM Sector for current and short-term scenarios, thus influencing the European AM Skills Strategy (WP4) and the AM pilots pilot courses to be performed in less than 6 month (WP5 - 2nd stage of Real Case Scenario) and less than 2 years (WP5 - Short term Scenarios).

Based on the findings, and considering the update of the International AM Qualification System (IAMQS) which already addressed the main Metal AM Profiles, partners concluded that the following would be developed in SAM, in order to tackle the specific skills needs mentioned above:

- Developing a Binder Jetting Process Competence Unit, to be integrated in the Metal AM Engineer, Coordinator and Operator Qualifications, as the Binder Jetting process is gaining relevance within industry;
- Developing a Polymers Designer Professional Profile/ Qualification, as Designers profiles are and will continue to be on demand by industry;
- Developing new transversal competence Units linked with Certification, Business and Sustainability bringing more awareness about AM potentialities across different industries and ecosystems.

The need for developing a Polymers Designer Qualification to be integrated in the IAMQS, was already concluded back in 2019. At this regard the interviews conducted with the Polymers experts, were of outmost importance to clearly assess the concrete needs towards the upskilled of the current workforce on AM design topics.

From the Training surveys, it was possible to characterize the main AM Training offers and derive recommendations on which learning methods to use according to specific content and skills categories, as well as the most suitable assessment tools, which will be integrated in D3.3 review.

The capacity building of the European, National and Regional Training Organizations with regards to equipment and skilled personnel is a key objective of addressing the challenges facing qualified personnel in the field of AM. The strategy to be followed to achieve the expected impact, which is to reduce skills gaps and ensure alignment of training offers and industry needs, is to strengthen collaboration between industry, education and standardisation activities.

The current provided training courses are well oriented and concentrated in order to fulfil important gaps of AM by using efficient training methods and tools. Also, it is obvious that the majority of the training organizations are willing to continue the trainings in the future. The leverage on existing funding programmes and mechanisms, namely given by the European Commission, is a key objective towards the investment in educational institutions, so that get into the position of training the next generations of designers, engineers and other specialists on manufacturing-capable 3D printers. It is clear that systematic collaboration between key industry and education stakeholders is essential to tackle the existing mismatch between the demand and supply of AM skills.

From the recruitment agencies, it was able to conclude that there was a significant interest of the agencies in having a platform to search for and post job offers for professionals in the field of AM/3D Printing. This platform, on the SAM project, is being created through the AM Observatory (https://www.ewf.be/sam/am-global-market/job-offers.aspx). Another important conclusion was that there has been an increasing job offers for AM/3D Printing professionals with a substantial growth from 2019 to 2021. Besides in terms of the sector demand for profiles in AM/3D Printing, they are aligned with the profiles previously identified by the industry.

6.1 Actions for 2021 and 2022

The workshops conducted enabled to identify the current and future needs of workers towards the different categories of skills, meaning **technological, entrepreneurship, green and digital skills.** In terms of **priorities** for the **development Professional Profiles Qualifications and Skills linked to the Real Case and Short-Term scenarios,** the following was validated by experts:

Real case (next 6 months)

- Development of new learning units **Business for AM competence unit** (covering entrepreneurial skills and costs) and as well as **Certification, Qualification and Standardization** competence unit (covering basic knowledge about certification and standards)

Short Term (within 2 years)

- Development of a new Design for Polymers Qualification, where 3D thinking skills will be integrated
- Development of technological skills addressing Binder Jetting for Independent and Advanced levels, although DED-LB was mentioned, the IAMQS already foresees this CU) – for 2 levels.
- Development of a transversal Sustainability Competence unit, where aspects of circular economy and LCA will be approached) to raise awareness.

Table 11 highlights the main indicators and priorities to be covered in SAM project for two scenarios.

Table 11 - Indicators and contents covered in SAM for real case and short-term scenarios

Scenario	Outcome
Real Case Scenario **Training to be delivered in less than 6 months** *** 2nd Round (2nd stage)**	1 new Professional Profile (PP)/Qualification (Q) **New Q/PP for Designers for Polymers (non-Engineers)** - 2 new learning unit **New CU for Certification/ Standardization** **New CU for Business for AM**
Short -term Scenario **Training to be delivered in less than 2 years**	- 2 new learning units instead of 1 new Professional Profile **- New CU for Binder Jetting (Independent and Advanced)** **- New CU in Sustainability for AM**

Next actions in the project until 2022 foresee to continue the identification of current needs with industrial organisations, educational centres and AM professionals /workers, in order to identify emergent AM skills gaps and needs. Also, the forecast with RTOs and the foresight analysis will be implemented. In parallel working sessions with experts will take place aiming design new qualifications/professional profiles for polymers and new units of learning outcomes. Moreover, the development of educational resources will be organized, along with training activities as summarized below (see Table 12).

Table 12 - Summary of actions to be conducted in SAM until 2022

Action Type	Description	Goal
Skills needs identification and forecast	Conduct auscultation with **industrial companies, Training centres and AM Professionals** on emergent skills needs and gaps **– Real Case Scenario – 2nd Round** **Target groups:** Companies, Training Centres and workforce	Identify the current skills to be addressed and compare with previous results (1 year);
	Conduct auscultation with **industrial companies, RTOs, Training centres, AM Professionals** on short terms skills needs and gaps **– Short term Scenario – 2nd Round** **Target groups:** Companies, RTOs, Training Centres and workforce	Identify the future skills to be addressed (3 years)
	Implement the **foresight** analysis for **skills** required the **next 10 years - Foresight Scenarios** **Target groups:** Small group of selected experts belonging to Industry, Research and technology centres	Identify the future skills to be addressed (10 years)
AM training design and tools development	**Working** sessions in collaboration with external experts **to develop new** qualifications and learning units **in less** than **6 months – 2nd stage of Real Case Scenarios** **Target groups:** Associated partners with relevant expertise belong to industry, academia, research centres, training centres, recruitment agencies, etc.	Design new AM Professional Profile /Qualification and Learning Unit Develop new learning and assessment tools (if applicable)
	Working sessions in collaboration with external experts **to review** qualifications and learning units **in less** than **2 years – Short Term Scenarios**	Develop new AM Professional Profile /Qualification and Learning Unit Develop new learning and assessment tools (if applicable) **Review** existing AM Professional Profile /Qualification and Learning Unit

	Target groups: Associated partners with relevant expertise belong to industry, academia, research centres, training Centres, recruitment agencies, etc.	Review learning and assessment tools (if applicable)
Train the Trainers	One training the trainers for preparing trainers to conduct pilots and to share pedagogical approaches and tools in AM training towards the implementation of the AM Qualification System. **Target groups:** Teachers and trainers with technological know-how in AM and related technologies	Share best practices on how to deliver training in AM; Fostering trainers pedagogical and technical skills
Guidelines developments	Guidance document containing **curriculum and tools –** to be applied in **2nd stage Of Real Case scenarios event** **Target groups:** Teachers and trainers	Support the implementation of training in AM
	Guidance document containing **curriculum and tools –** to be applied in **Short term Scenario event** **Target groups:** Teachers and trainers	
AM training Delivery / Pilot testing	Pilot testing of Qualification/ PP and learning unit **- 2nd stage Of Real Case scenarios** **Target groups:** Students	Validate the capacity to undertake the design and/or review of Qualifications Validate the adequacy, relevance of the curriculum, pedagogical approaches and tools in the context of AM training
	Pilot testing of Qualification/ PP and learning unit **- Short term Scenario** **Target groups:** Students	
	Pilot testing of Qualification/ PP and learning unit **- Real Case and Short-term scenarios** **Target groups:** Students	**Implement** SAM's final forecast methodology
AM Qualification Catalogue	Online catalogues containing information on Available training in AM in Europe -two editions will be issued **Target groups:** **End-users**	Promote AM Training in Europe

7. Annexes

7.1 Agenda for the AM Skills Needs Analysis Workshop

SAM 5th MEETING FINAL AGENDA

Online meeting with Microsoft Teams			
	Day 1 – 2nd December		**Meeting Link access**
	Overview of project progress (EWF)		
Morning 10h00 13h00 CET	**10.00**	• Welcoming • TM5 meeting agenda • Approval of TM4 minutes • Overview of project progress – follow up	All partners
	Achievements and next 6 months (WP leaders: IDONIAL, EC Nantes, LAK, EPMA, CECIMO, ISQ)		
	10.30	**Presentation order: WP2, WP3, WP4, WP5** (30-45 minutes each) • Achievements by M24 • Deliverables under development • Starting activities until M30 • Workplan review and Next actions	
Afternoon 14h00 16h10 CET	**Achievements and next 6 months (WP leaders: IDONIAL, EC Nantes, LAK, CECIMO, ISQ)**		
	14.00	**Presentation order: WP8, WP10** (30 minutes each) • Achievements by M24 • Deliverables under development • Starting activities until M30 Workplan review and Next actions	
	Technical Discussions *		
	15.10	Time for technical discussion on WP8 - lead by CECIMO (1h00)	
Breaks	***Coffee Break_ Morning:**11h15 **Afternoon:** 15h00 **(10 minutes)*** ***Lunch Break**_13h00 to 14h00 **(1h00 minutes)***		

	Day 2 – 3rd December		
	2ND Internal Workshop to Analyse Data and Define Priorities – LAK		
Morning 10h00 13h00 CET	**10.00**	**Workshop topics:** • Introduction to workshop dynamic (5 minutes) • Groups analysis (30 minutes) • Group 1 - Data from Training Centers Survey • Group 2 - Data from Workforce Survey • Group 3- Data from Companies Survey • Discussion and wrap up of major findings (55 minutes)	List of partners (last page)
	Technical Discussions *		
	11.30	Time for technical discussion on WP5 - lead by LAK (1h30). 1st /2nd stage of pilots and reporting	
Afternoon 14h00 16h40 CET	**Technical Discussions ***		
	14.00	• Time for technical discussion on WP10 - lead by ISQ (2h30). Presentation of RRI strategy document state of development by each involved partner (10 minutes, each). Order of	

SAM 5th Meeting Agenda – Online meeting
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Annex 1 - Agenda of the 2nd workshop data analysis

7.2 Agenda for the AM Skills Needs Validation Workshop

AGENDA – 27th January 2021

10.15	**Welcome & Opening**	
10.20	**Ice-break / Presentation** *(Moderation: Adelaide Almeida, EWF/ SAM project Coordination)*	
10:45	**The European Sector Skills Strategy for AM – SAM Project** *(Speaker: Adelaide Almeida)*	
11.00	**SAM results regarding skills needs and gaps in AM:** *Which are the trends concerning AM training courses? Which formats and levels of training are available? Which skills are required by professionals and companies?* *(Speaker: Yvonne Wessarges, LAK / Leader for Piloting the Methodology for creating and revising Professional Profiles)*	
11.35	**1st International AM Qualification System & the role of the AM Councils** *(Speaker: Beatriz Lopez, EWF / AM System Manager)*	
12.00	**Coffee STOP** *(10 minutes)*	
12.10	**Hands on for the Validation of Skills in AM (Breakout rooms)** *(Moderation: Paula Queipó, IDONIAL / Martin Schaefer, SIEMENS)*	
	Group 1 - Qualification Council Experts Defining the AM Designer for Polymers Profile for AM industry	**Group 2 – Industrial Council Experts** Defining the trends and priorities for qualified personnel working in AM industry
13:15 -13.30	**Wrapping up on the skills priorities for the AM Sector in Europe**	

Annex 2 - Agenda of the 2nd workshop to validate skills needs

7.3 List of organisations attending the AM Skills Needs Validation Workshop

Annex 3 - List of attending organisations