SECTOR SKILLS STRATEGY
IN ADDITIVE MANUFACTURING

4th Report on the Analysis and Validation of Needs

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Contents

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.

During 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 needs to be addressed in less than 1 year.
- Scenario 2: Short-term, how relevant skills / trends need to be addressed in the less than 3 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 scenarios**. It is the fourth Report on the Analysis and Validation of Needs, which correspond to the last round of auscultation with key target groups, namely Companies, AM Workers and Recruitment Agencies.

The report addresses the priorities in terms of AM skills development using a combination of methods (e.g. surveys and workshops) to collect data from industrial organisations and workers operating in different industrial sectors. Moreover, the document addresses the comparative analysis regarding prior rounds of auscultation and the priorities trends evolution.

In a nutshell, the skills gaps and demands by industry for real case scenario revealed that:

Table 1. Skills gaps and demands for real case scenario and target group

Skills	**AM Workers Skills Gaps** (Real Case Scenario 2023 survey)	**AM Companies Skills Gaps** (Real Case Scenario 2023 survey)
Technological	• Certification & Qualification • Simulation • Research & Innovation	• AM Processes • Numerical Modelling / Topology Optimisation • Design
Entrepreneurial	• Identify needs and challenging opportunities to create value • Develop creative and purposeful ideas/solutions • Learn through experience	• Identify needs and challenging opportunities to create value • Develop creative and purposeful ideas/solutions • Work with others
Green	• Reuse/recycling AM materials and products • Life cycle analysis (LCA) • Resource efficiency management	• Reuse/recycling AM materials and products • Life cycle analysis (LCA) • Resource efficiency management
Digital	• Digital data analysis (artificial intelligence/machine learning) • Digital data management (big data, statistics) • Ability to think 3D	• Digital data analysis (artificial intelligence/machine learning) • Digital data management (big data, statistics) • Ability to think 3D

AM Companies (2023 survey)	**Materials**	**Required AM Professional Profiles**	**Future upskilling needs**
	Metals followed by Polymers	**Process engineer, operator/technician and AM designer**	**AM processes and design**

The validated skills data will be used as reference to support the European AM Skills Strategy and to revise existing training courses and develop new ones for the IAMQS (International AM Qualification System).

2. Introduction

SAM project is a strategical approach to skills development 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 last round of forecast methodology addressed within SAM, consists in a continuous market research to determine skills mismatches and gaps by implementing a set of online surveys with representatives from industry / employers, workers in AM and recruitment agencies.

In parallel, other complementary activities were conducted using forecast methods, enabling to discuss on future AM applications, challenges and solutions to tackle AM skills needs.

After collecting the data, their analysis was performed during an internal workshop / working session, thus defining the skills priorities and areas that needed further exploitation in the next stage of data collection through interviews. Four criteria were used to determine the priorities to tackle the above-mentioned skills needs and gaps, which were: sectors relevance in alignment with ISO activities, urgency, impact on employability and relevance towards capacitating the AM workforce.

Finally, the last step of this auscultation process consisted in the validation of skills needs with external stakeholders during a dedicated workshop.

In this context, the current report, developed in the framework of the AM Observatory (Work package 4), is the baseline to define the next activities to be developed after the project ending. The report gathers the main findings and conclusions taken from the application of developed forecast tools (Work package 2).

In terms of structure, the report is organised in six sections, as follows:

- Section 3 “Applied Methodologies” - includes the description of the applied forecast methodologies;
- Section 4 “Real Case Skills Needs Results”– addresses the results achieved with the implementation of surveys and workshops.
- Section 5 “Results Comparison” - addresses the comparison between findings, namely the comparison of needs evaluation from 2020 to 2023, as well as the companies vs workers survey results.
- Section 6 “Conclusions”- addresses the validated results, main conclusions and reflection on the next steps, thus pointing out the way to follow within the IAMQS to development and update in terms of technological, green, entrepreneurial and/or digital skills.
- Section 7 “Annexes” - includes all annexes and supporting documents (e.g. workshops agendas and the list of participating organisations)

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

Online surveys were conducted for gathering data among stakeholders, which were promoted through personal emails, included in newsletters and disseminated during specific events and networks, such as the AM-Platform, CECIMO, EPMA, EWF, among others. Also, a QR code was created to facilitate the access via smartphone or another electronic device. Three surveys were available from December 2022 to March 2023, with different aims and addressed to different target groups, namely:

- **AM companies /employers -** aiming to identify what kind of Additive Manufacturing skills companies are looking for considering their emergent needs
- **AM professionals / workers -** aiming to identify current AM skills, knowledge and new job needed within one year.
- **Recruitment agencies -** aiming to characterize the current AM /3D printing labour market job opportunities and employability in Europe
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3.2 Workshop for data analysis

The "4th workshop for data analysis" took place online on 5th April 2023, gathering 16 participants, belonging to SAM consortium (see **Error! Reference source not found.**). A specific agenda was established to guide the working session implementation (see Annex 8.2).

The objectives of the internal workshop were the following:

- Analysis of replies from Industry concerning AM skills needs to be addressed in 1 year (Real Case Scenarios)
- Identification of gaps: Professional Profiles, Skills and knowledge
- Evolution of needs comparing with industry replies from 2021 and 2022
- Reflection on the implications of the results for IAMQS
- Identification of priorities & topics to be validated with external organizations

EWF leader of WP4 was responsible for conducting the workshop introduction and groups moderation. To facilitate the results analysis, two groups were set to discuss the different surveys results conducted with industry workers and companies. Partners were equally grouped into to guarantee expertise and gender balance.

Group 1 (composed by POLIMI, Materialise, UBRUN, FA, IDONIAL and IMR) tackled the results from the companies survey, while group 2 (composed by EWF, MTC, EC Nantes, LAK, LORTEK, LMS and ISQ) tackled the AM workforce survey results, 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 1 year) scenario.

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

3.3 Workshop for the validation of skills needs

The "4th Workshop to validate skills needs in AM" took place on 27th April 2023, in Leuven (Belgium) focusing on validating the relevant AM gaps for technological, green, digital and entrepreneurial skills, as well as the required profiles and knowledge required by industry in real case scenarios.

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 (refer to the list of participating organisations in Annex 8.3 and agenda in 8.4).

During the hands-on, the moderators used *slido* to launch and monitor the discussion. A detailed description on the workshop conclusions can be found in chapter 4.

4. Real case scenarios skills needs results

The results of the survey, which focused on current industry needs, are reported in this chapter, which includes findings gathered among AM Workers, AM Businesses (companies and employers) and Recruitment agencies. The applicable surveys cover a range of subjects, including general information and background, AM skills and professional profile needs, relevance of various skills categories, and AM employability data, to name a few. Within SAM, skills have been classified into four different categories:

- ***Technological skills*** defined as "Ability to apply knowledge and use know-how to compete tasks and solve problems" [within specific activities]" (Adapted from CEDEFOP 2008)
- ***Digital skills*** defined as "range of abilities to use digital devices, communication applications, and networks to access and manage information. They enable people to create and share digital content, communicate and collaborate, and solve problems for effective and creative self-fulfilment in life, learning, work, and social activities at large" (UNESCO, 2022)
- ***Entrepreneurship or entrepreneurial skills*** defined as "transversal key competence applicable by individuals and groups, including existing organizations, across all spheres of life" or "when you act upon opportunities and ideas and transform them into value for others." The value that is created can be financial, cultural, or social." (ENTRECOMP, 2016)
- ***Green skills*** defined as "knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society (CEDEFOP, 2015)
-

4.1 Findings on surveys conducted with the AM workforce

The survey with industry was carried out from January to March 2023 among AM workers. A total of 102 participants responded to the survey. This number of replies corresponds to a 157 % increase of participation in comparison with the previous auscultation period (Jan-Feb. 2022) and 74 % participation rate compared to the first round (Oct- Nov. 2020). However, in this last round of surveys held between January and March 2023 only 71 participants answered to all the questions, that is 69% of the total number of respondents.

General information and background

In terms of general information and participants' background, the first question dealt with the type of organization in which people are working. Respondents participating in the surveys were working in companies of different sectors such as aerospace (18%), automotive (18%), energy (19%) and industrial equipment and tooling (23%). It is worth mentioning that almost 95% of the participants were highly qualified profiles (designers, process engineers, material engineers …) and only 5% were representing operators and technicians. Regarding experience, 75% of the respondents had more than two years' seniority in that company. Participants showed to have experience and knowledge in different domains or stages of the value chain as can be observed in Figure 1.

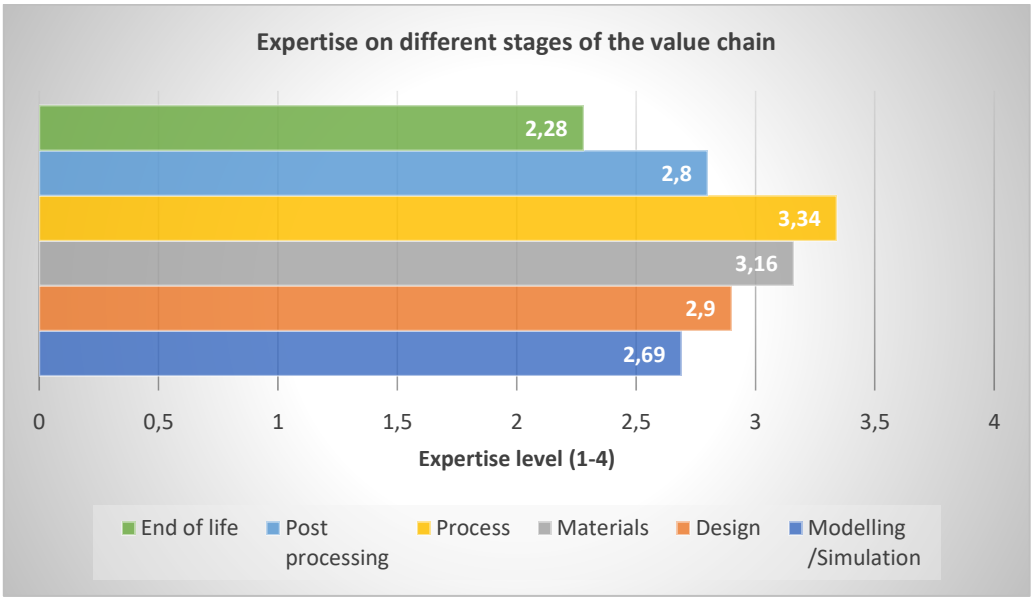


Figure 1. Workers´expertise level on different stages of the value chain.

Necessities on each category of skills for real case scenario (skills to be addressed in one-year time)

During the survey, the industrial AM professionals were asked to identify the different skills categories which they will need to develop or improve according to their current and future activities in 2023-2024. Skills were classified in four different knowledge domains or groups (technological, digital, entrepreneurial and green) and workers were asked to prioritize the relevance of skills in each of the domains.

Technological skills

This round of surveys has shown **certification & qualification** (62%), **simulation** (55%) and **research & innovation** (54%) to be the most important technological skills to be developed or improved within the next year. Other skills related to design and manufacturing process were also chosen as important but with a lower relevance (around 50%).

Digital skills

As for the digital domain, the three most relevant skills were **digital data analysis** (machine learning, artificial intelligence) (71%), **digital data management** (big data, statistics) (56%) and **ability to think 3D** (27%).

Entrepreneurial skills

In terms of entrepreneurial skills needs **Identify needs and challenging opportunities to create value** (68%), **develop creative and purposeful ideas/solutions** (58%) and **learn through experience** (50%) are the entrepreneurial skills that have been considered to be most relevant within a year by respondents.

Green skills

The top three green skills mentioned by workers were **reuse/recycle AM materials and products** (70%), **life cycle analysis (LCA**) (63%) and **resource efficiency management** (44%).

4.2 Findings on surveys conducted with AM industry (Companies)

The survey among industrial organisations was carried out from January to March 2023, gathering a total of 55 replies. This corresponds to an 98% of participation rate in comparison with period of Oct- Nov. 2020, a participation of a 76% regarding to the previous period (Jan-Feb 2022). Nevertheless, 83% of participants taking part in the last round of surveys (Jan-Mar 2023) answered to all the questions, that is, 46 respondents.

General information and background

49% of respondents belong to a large company (≥ 250 employees) and 20% to a start-up (≤ 9 employees) while 15% of participants belong to small sized enterprises (10-49 employees). The remaining 16% belong to medium companies and other type of enterprises. Regarding countries where companies are based, respondents belong to 14 countries. The great majority of respondents (89%) belong to European countries, 38% from the UK, 11% from Spain and 9% from Germany for instance. 5%% of the participants were from the USA and the remaining 5%5from other countries.

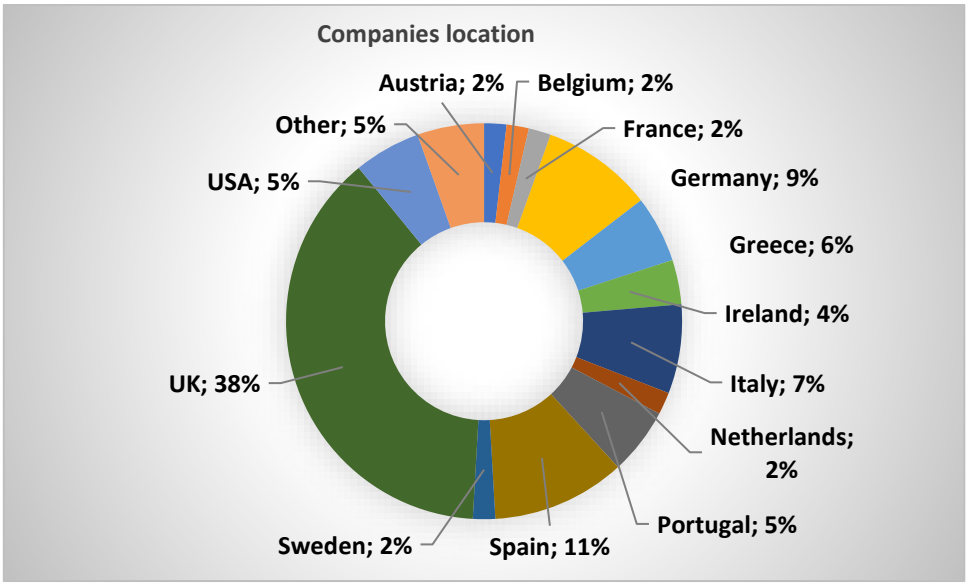


Figure 2. Location of responding companies.

It is worth mentioning that 96% of the respondents are currently using AM. The most used material types are metals (36%) and polymers (30%), followed by composites (12%), multi-materials (7%), biomaterials (7%) and ceramics (5%). As for AM processes, Powder Bed Fusion (37%) and Material Extrusion (22%) are the most widespread technologies, followed by Vat Photopolymerization (13%), Directed Energy Deposition (11%), Binder Jetting (11%), Material Jetting (8%) and Sheet Lamination (1%).

Necessities on each category of skills for real case scenario (skills to be addressed in one-year time)

In the same way as with workers, companies were asked to identify the different skills categories which they will need to develop or improve according to their current and future activities in 2023-2024. Skills were classified in four different knowledge domains or groups (technological, digital, entrepreneurial and green) and priorities of companies regarding those skills are summarized as follows.

Technological skills

As for the technological skills, process and design/simulation related skills are the ones considered as more relevant within one year timeframe, being those skills **AM processes** (71%), **numerical modelling/topology optimization** (63%) and **design** (61%).

Digital skills

Regarding the digital domain, the three most relevant skills were **digital data analysis** (machine learning, artificial intelligence) (65%), **digital data management** (big data, statistics) (63%) and **ability to think 3D** (59%).

Entrepreneurial skills

Identify needs and challenging opportunities to create value (78%), **develop creative and purposeful ideas/solutions** (71%) and **work with others** (55%) are the entrepreneurial skills that have been most relevant within a year by respondents.

Green skills

The top three green skills were **reuse/recycle AM materials and products** (71%), **life cycle analysis (LCA)** (57%) and **resource efficiency management** (43%).

Upskilling/reskilling and hiring prospects for companies

Companies were also asked to draw AM professional profiles that they could potentially hire in one year's time as well as to identify the needs of upskilling or reskilling of current workers. Answers to these questions are presented in Figure 3 and Figure 4.

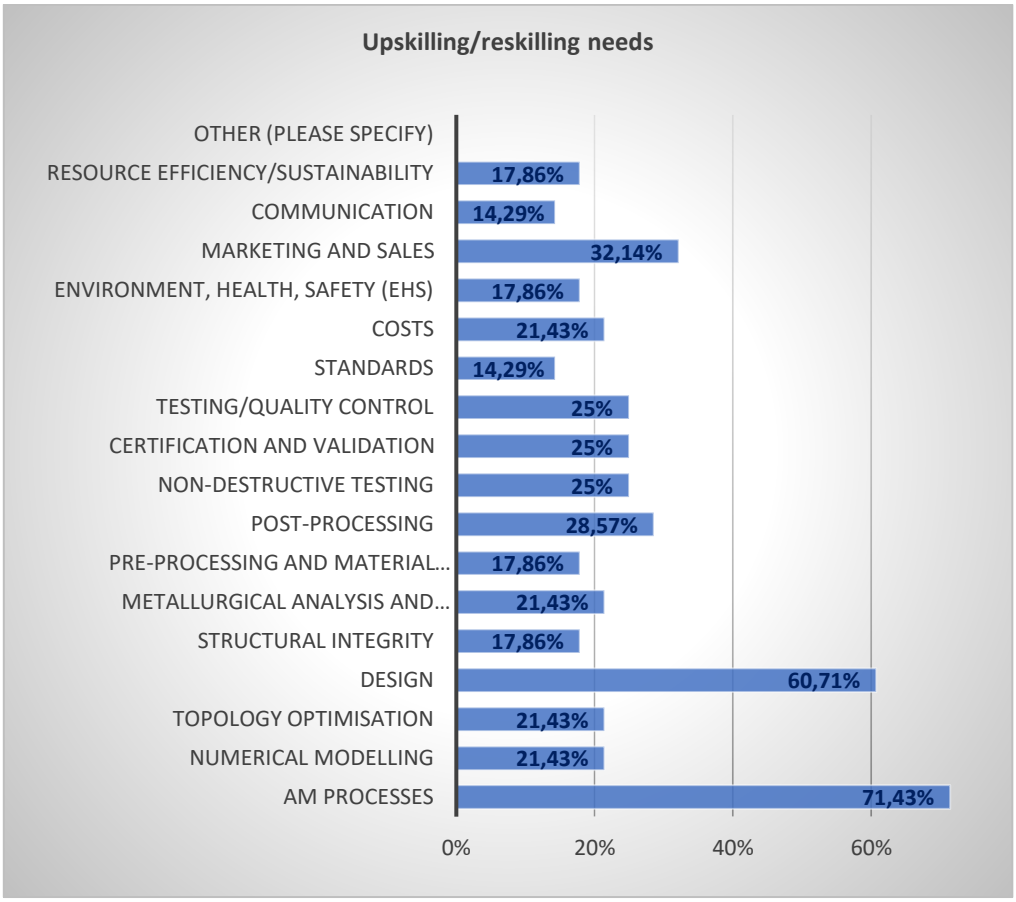


Figure 3. Upskilling/reskilling needs identified by companies.

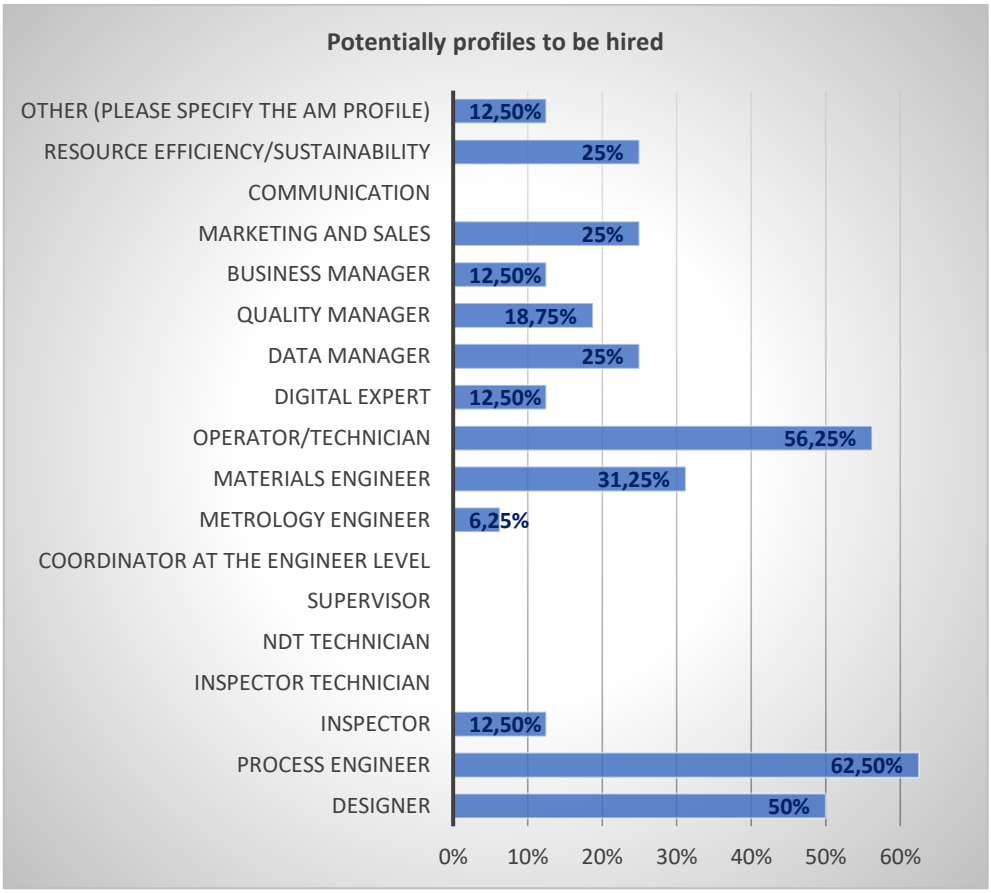


Figure 4. Potential AM profiles to be hired within a year.

On the one hand, from the first graph it can be clearly seen that companies **identify upskilling or reskilling needs related to AM processes and design**. Those were the most voted possible answers with 71% and 61% respectively. On the other hand, companies are planning to hire AM professionals with profiles as **process engineer** (63%), **operator/technician** (56%) and **designer** (50%). From these results, it is remarkable that identified upskilling/reskilling needs completely match with companies´ hiring plans as both skills and profiles are AM process and design related.

4.3 Findings on surveys conducted with Recruitment Agencies

The Recruitment Agencies survey aimed to characterize the current AM / 3D printing labour market job opportunities and employability in Europe, by inquiring relevant national and European HR and Recruitment agencies. The survey was carried out for 3 months, from 7th December 2022 to 2nd March 2023, gathering 6 (six) answers. Considering the low participation in the survey, it was impossible to draw robust conclusions regarding the most demanded profile by labour market and specific sectors; characteristics of the growth demand of AM workers, among other features.

Despite this limitation, findings are generally described in the section.

In terms of origin (Figure 5) the Recruitment agencies replying to survey were mostly based in the United Kingdom (2 replies) followed by Spain, Portugal, Italy, Bulgaria, Croatia and Canada (1 reply each).

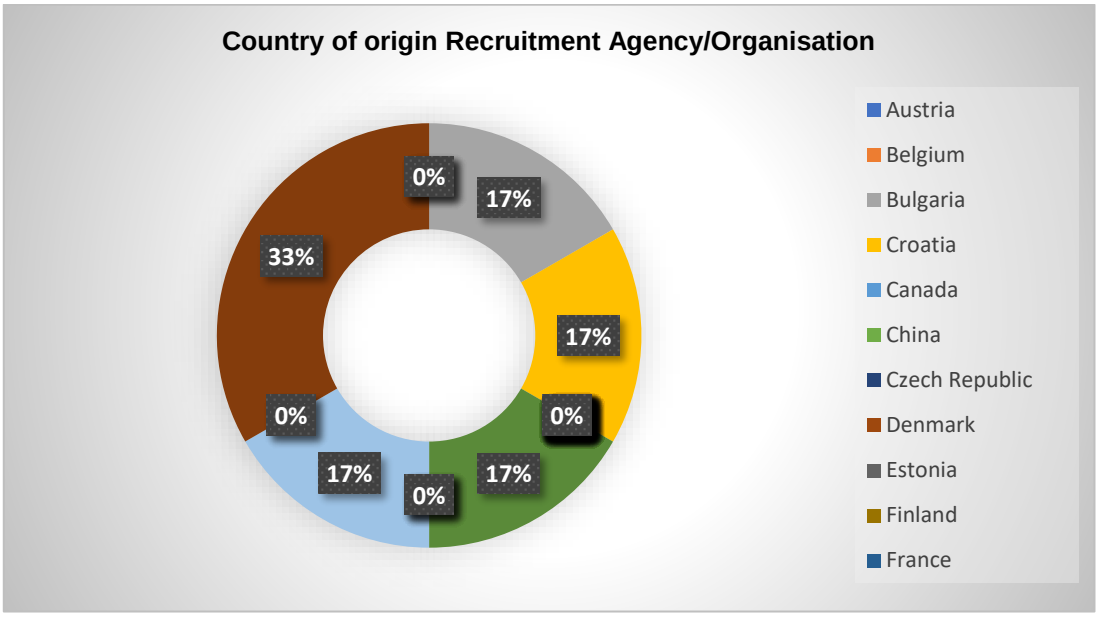


Figure 5. Recuritment agencies country of origin

Agencies mentioning to have direct hiring requests (60%), reported, that they came mostly from companies in Aerospace & Defence (100%) followed by Automotive, Consumer Goods, Health, Industrial Equipment and tooling (67%) and lately by Construction (33%)., as illustrated in Figure 6.

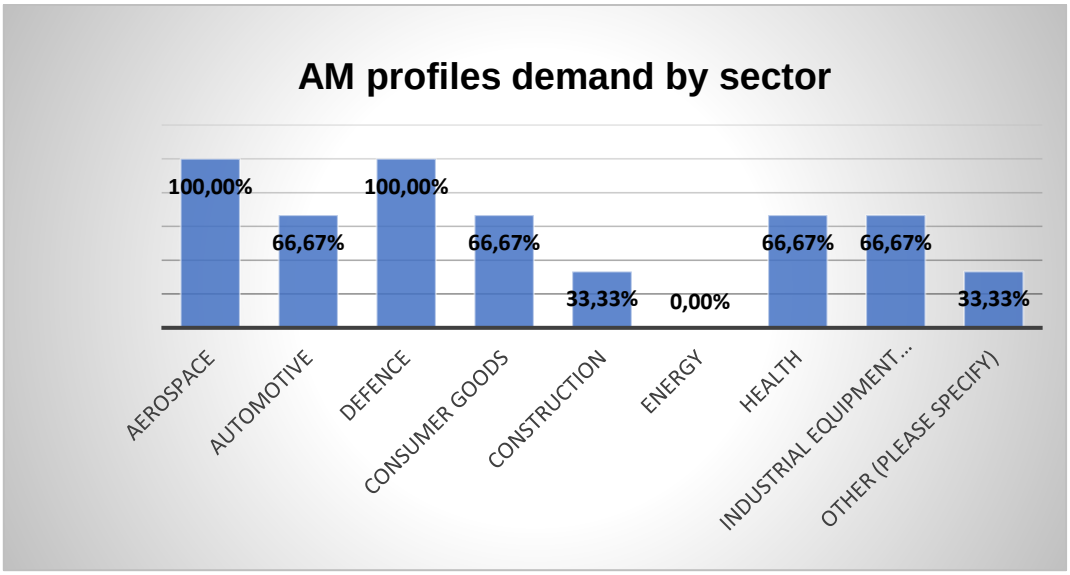


Figure 6. Demand of professionals by sector of activity

The most requested AM profiles (Figure 7) were the AM Operator and Process Engineers, followed by Materials Engineer.

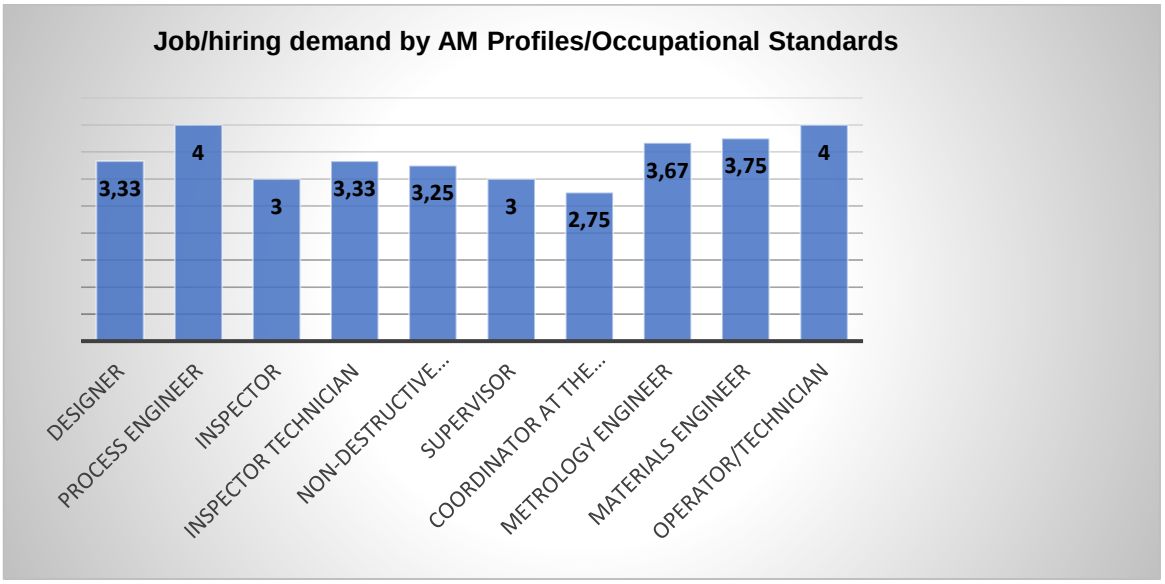


Figure 7. Hiring demand by AM Profiles /Occupation

Despite the low number of replies, additional sources of data, such as Formnext, can confirm the need for hiring AM workers (1535 job vacancies). Being the 9 top hiring companies EOS, Formlabs, Materialise, Stratasys, SLM solutions, GE Additive, 3D Systems, Desktop Metal and Markforged (source: Formnext, 2019).

A possible interpretation for the above-described findings, it is that:

- AM companies are relying on their own tools and resources (e.g. HR department) to recruit AM professionals instead of hiring Recruitment agencies services when it comes to hire people
- The Recruitment Agencies are not aware about the Additive Manufacturing Technology
- Agencies focus on common generic Occupations and Professional Profiles description, linked with specific Jobs requirements
- Agencies have a national focus for advertising job offers instead of European
-

It might be useful to consider the IAMQS framework to support companies and Agencies in posting AM job vacancies.

4.4 4th Workshop to analyse skills needs – Internal Workshop Results

As mentioned, to facilitate the results analysis, two groups were set up to discuss results collected among industry workers and companies.

After the group's discussion, each group presented their conclusion to the larger group. Their conclusions on current skills gaps required professional profiles and /or qualifications and priorities for skills development are summarized in the table.

4th WORKSHOP DATA ANALYSIS & VALIDATION OF NEEDS _ DATA ANALYSIS OVERVIEW
Total responses:
163 replies in total 102 (workers) +55 (companies) + 6 (Recruitment agencies)
Wrap up– Conclusions

Domains requiring improvements (comparing Workers / companies?)

- **Workers** wish to learn from **certification and qualification** & develop their digital skills
- Knowledge and skills on simulation, research and innovation continue to be the most required areas of improvements by workers;
- **Companies** identified as required AM Professional Profiles /Occupations: **Designers,** followed by Materials Engineers, Process Engineers and Operators
- Companies identify to need capacitated staff in **AM processes, followed** by Design, Metallurgical Analysis and Characterization and lately in Non-Destructive Testing

Data to be further explored

- To which extend shall digital skills be developed? To check the real impact and need of digital skill.
- How to address digital skills for AM personnel in a proper training programme?

Implication for the IAMQS

- Workers Training references are Short Courses, case studies and practical activities
- No changes in terms of needs of green and entrepreneurial Skills

Next actions

1) Assess prediction capability of our yearly survey method. Current 1 year scenario is comparable to the 3 years scenario of our first survey in 2020?
2) Priorities from companies (and workers) do not seem to change a lot. Is the AM technology evolving so quickly as we were considering or has it already reached a certain maturity level? If so, training programmes are already suited for the needs of the market: AM growing 4 times faster than market and with new technological advances and new applications. The foundations for reaching those advances are set from the perspective of the education and training of AM professionals.
3) Check real impact and need of digital skill.
4) Consortium conclusions in this domain (digital skills) are influenced by the short list of potential answers. We have maybe overestimated critical digital issues like monitoring, control, cybersecurity, SW development, AI (ChatGPT)… that are still on a research level but demanded by industrial companies. Should we consider including these in the training programmes or check if our training programmes are attractive for non-engineering profiles with higher digital skills (mathematicians, physicists, data analysts, SW developers, …)

The actions identified during the internal workshop were used as input to drive the discussion during the validation workshop with external stakeholders described below.

4.5 4th Workshop to validate skills needs - External workshop results

The “4th Workshop to validate skills needs in AM” enabled to explore the 'open questions’ on the relevant AM gaps on digital skills, the technology development path and its impact on AM Skills required by industry.

Moreover, the workshop entailed the presentation of:

- AM education and training framework: IAMQS
- Industrial Skills needs (latest findings)
- Evaluation of skills needs and prediction capability
- Forecast perspectives (2021-2030)
- AM Skills Strategy Roadmap for 2023 and feedback collection

An interactive discussion was promoted towards gathering the AM experts opinion on :

- how the AM technology is growing in terms of processes and its impact towards skills development until 2030 ?
- which digital skills are required by companies?

The profile of the AM experts

The workshop counted with the participation of 45 experts from the AM community in Europe (a total of 19 countries represented), corresponding to AM companies (34%), academia (28%), research centres (16%), policies bodies (13%), (e.g. EC, CECIMO), as well as standardization bodies (3%), specific AM clusters (3%) (e.g. Greek Hub or the Danish hub) and VET. Experts coverage and background are illustrated in Figure 8.

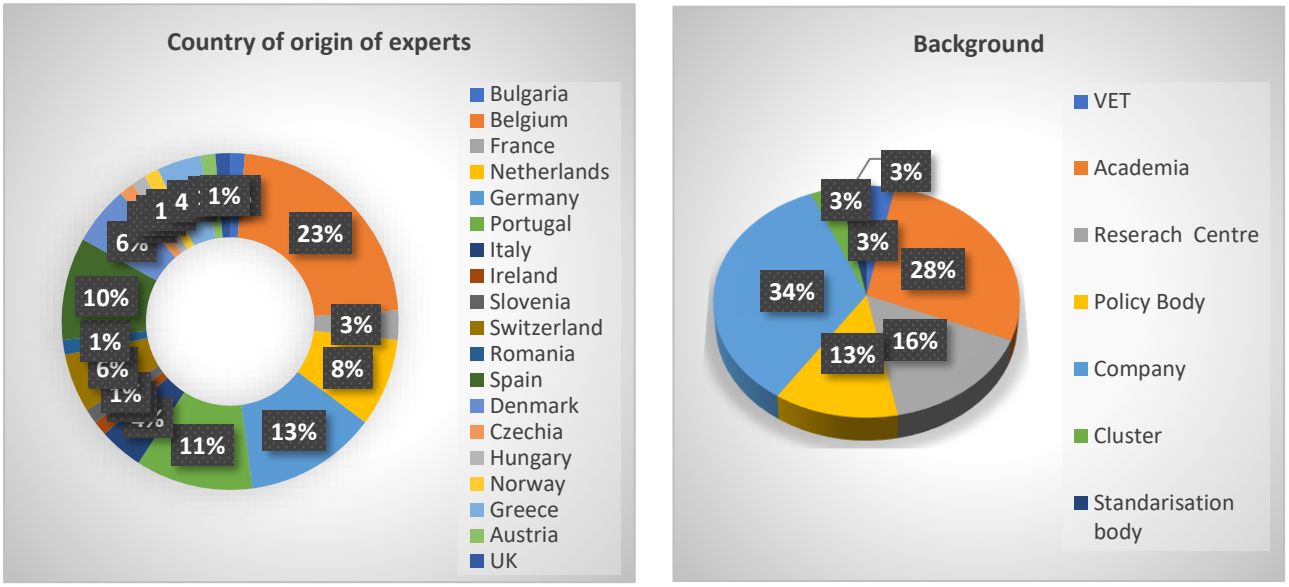


Figure 8.AM Experts profiles

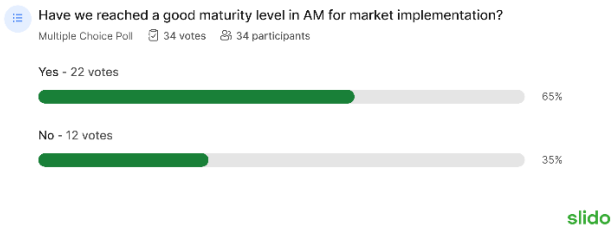
Expected growth by AM technology regarding AM processes

As identified in prior surveys, the priorities in terms of required technological skills from workforce and companies do not seem to change significantly over the timeframe of three years. The consistency of results could be an indicator to conclude that AM technology is not evolving so quickly or that it has already reached a certain maturity level .

To validate this hypothesis, experts were challenged to think about: How the AM technology is growing as whole (slidoQ1)? How are AM processes changing specifically slidoQ2)?? And what is the impact of AM processes change in terms of skills development (slidoQ3)? Results of the slido and the discussion are described below.

Additive Manufacturing evolution behaviour and impact on required skills

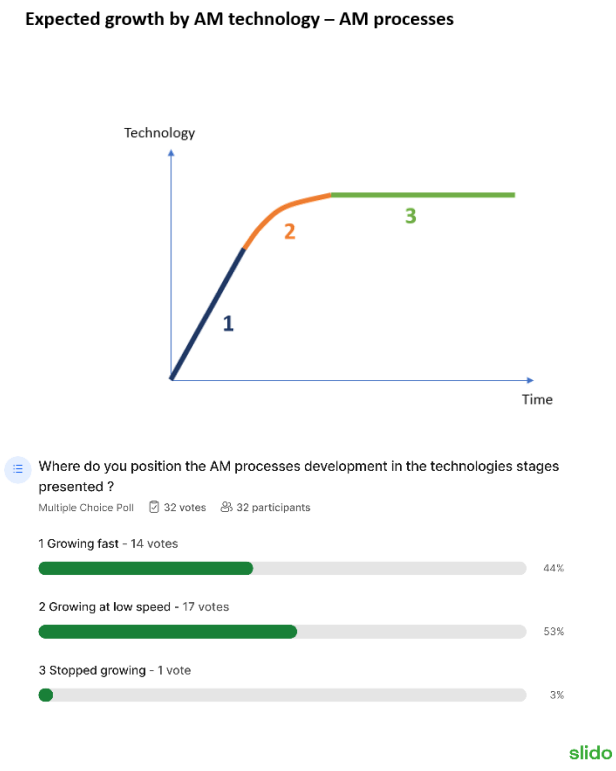
SlidoQ1. Have we reached a good maturity level in AM for market implementation? 65% answered "yes"against 35 %.



Comments

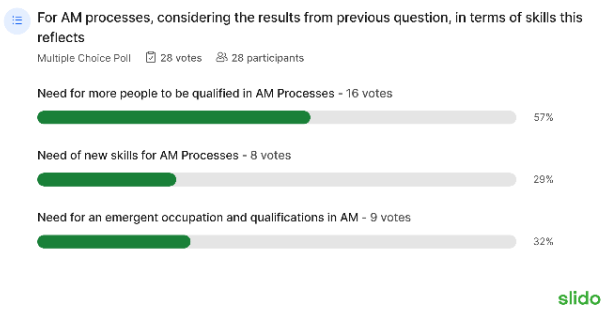
- AM is not mature enough due to economic reasons. Some companies prefer to buy additively manufactured pieces from the market instead of producing them themselves. Because of two reasons. Firstly, training qualified personnel takes time and costs money. Secondly, producing qualified pieces is not always affordable.
- AM is mature enough since it has 18 million market shares. Additionally, AM standards are maturing. In spite of this, AM should continue to grow by training people at all levels.
- It's not matured yet. Software and machines are still developed.
- Deeper life cycle assessment process are missing
- Investment should be done for training product designers to be more innovative regarding sustainability aspects
- AM technologies are fast, but they are too expensive now.

SlidoQ2 - Where do you position the AM processes development in the technologies stages presented? 53% mentioned at "low speed" and 44 % "fast grow" and 3% responded that "it had stopped growing".



Comments

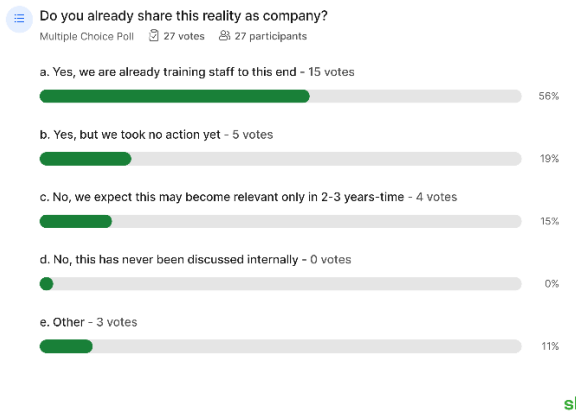
- Growing is stacking depends on materials such as ceramics.
- Regarding the research area AM growing is again accelerated. The use of technologies is extending in new areas.
- Metals with all new laser technology growth very fast regarding research.
- Creativity and capability to compare products market and value
- Digital transformation is about to start and will require more digital experts, datalike managers, niche experts for processes and algorithms, etc.
- There is growing knowledge in the research area.
- Technology industries growing faster than we expected are considering investing in AM technologies, but not that fast.
- There is no revolution but there is evolution

Additive Manufacturing evolution behaviour and impact on required skills	
SlidoQ3. For AM processes, considering the results from previous question, in terms of skills this reflects. 57% responded that "need for more people to be qualified in AM process"; 32% responded that "need for an emergent occupation and qualifications in AM"; and 29% responded that "need of skills for AM processes".	**Comments** • Software is so good in these days, and young people can easily handle with thanks to these ones. So, software is doing many things without requiring high qualification. • The gap between experienced people and young people's skills/knowledge is getting larger. • The new machines require new skills; a system should be developed that workers at home need to exchange their knowledge with each other. • New skills are required for implementation of chain not only factory but also business. • People need to understand "What really AM is?", skills should not be too complicated
	

Digital skills needed by companies

Conclusions obtained for the digital skills need show the same list of required skills without identifying new ones. This consistency in the findings led to infer that the results could have been "influenced" by the type of questions and predefined selections options. In this sense, this discussion aimed to validate: If there is a growing interest of industrial companies for digital profiles (slidoQ4)? ; And if so, which are the digital skills needed (slidoQ5), which professional should benefit from digital skills training /development (slidoQ6)? How to approach in specific courses (slidoQ7)? Slido results and the discussion are described below.

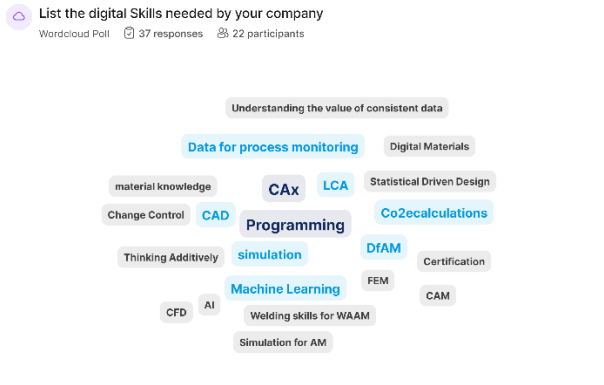
Digital Skills	
SlidoQ4. Do you share this reality as company? Among 20 responses, 50% of them responded that "Yes, we are already training staff to this end"; 20% responded that "Yes, but we took no action yet"; 15% of responded that "no, we expect this may become relevant only in 2-3 years-time" and 15% of responded that "other".	**Comments** • Universities and industries' perspectives are not the same. • A university knows digital skills importance, they got an application, but they did not use it yet.



- One company got a software, and they already train their people.
- Regarding digital skills, you need to find something you already can do and something that challenges you.
- University is using/teaching software in laboratory to student to prepare them to companies' needs.
- Digital skills training depends on companies' capability of investment. For example, many small companies stack old machines since having new machines does not add any value to them.

SlidoQ5 – List the digital Skills needed by your company

The most mentioned were: Programming, CAD CAx, Machine learning, Data process monitoring



Comments

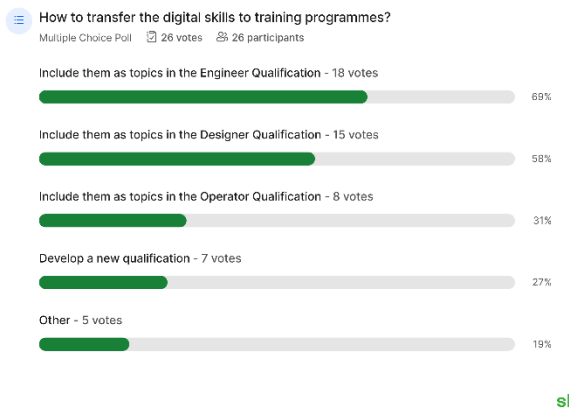
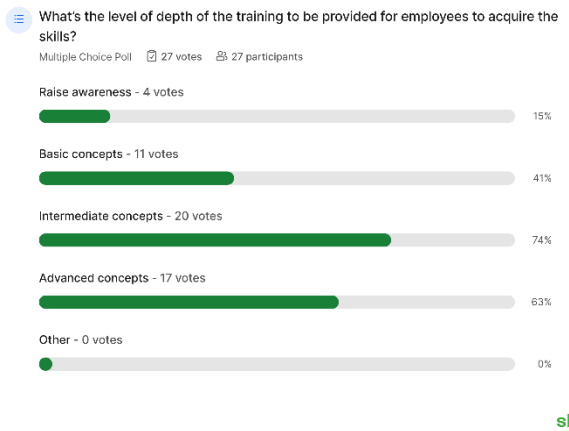
- CAx: Computer aided design and some new digital skills are required
- Programming digital skills are required i.e. research environment commercially available; one or few languages are required
- The complex simulation programs could become more straightforward.

How to transfer the digital skills to training programmes?

Among 25 responses, 68% of them responded that "include them as topics in the Engineer Qualification"; 64% of them responded that "include them as topics in the Designer Qualification"; 32% of them responded "include them as topics in the Operator Qualification"; 24% of them "develop a new qualification"; and 20% of them responded that "other".

Comments

- In terms of new qualification sometitle missing program and substracting process.
- AM digital engineer should be developed as a new qualification.
- Standardization for certification skills are required

	
What's the level of depth of the training to be provided for employees to acquire the skills? Among 20 responses, 73% of them responded that "**intermediate concepts**" > 65% of them responded that "**advanced concepts"** > 42% of them basic concepts and 15% of them responded that "**raise awareness**"	**Comments:** None
	

5. Results Comparison

5.1 Workers vs companies surveys results

In this section the results of the surveys conducted with workers and companies in 2023 are compared and key findings are summarized. It is worth noting that 102 answers were obtained from the workers' surveys and only half of the responses were from companies, that is 55 answers.

On one side, regarding technological skills, workers think that knowledge will be required within one year time in domains as, certification & qualification, simulation and research and innovation. On the other side, companies find more relevant skills like AM processes, numerical modelling/topology optimization and design. In a first glimpse, and comparing the top 3 relevant skills, workers´ and companies´ priorities seem not be in line. However, workers also consider relevant process and design & simulation related skills but to a lesser extent.

In the digital domain, for both, workers and companies, the most relevant skills are digital data analysis (artificial intelligence, machine learning), digital data management (big data, statistics) and ability to think 3D. Neither the

skill categories nor the order of priority changes between workers´ and companies´ results, so it can be concluded that the perceptions of digital skills needs perfectly match.

Same as for the entrepreneurial skills: Identify needs and challenging opportunities to create value and develop creative and purposeful ideas/solutions are the top ranked ones for both workforce and companies. The third most relevant skill differs one from another, being 'learn through experience' the top three for workers and 'work with others' for companies. Once again priorities do not seem to change significantly as far as entrepreneurial skills are concerned.

In the case of green domain, workers and companies are in complete agreement. The most voted skills for both are 'reuse/recycling AM materials and products', 'life cycle analysis (LCA)' and 'resource efficiency management'.

Table 2. Comparison of skills need priorities for workers and companies.

	TOP 3 SKILLS	
	Workers	Companies
Technological	Certification & Qualification (62,5%)	AM Processes (70,6%)
	Simulation (55,7%)	Numerical Modelling / Topology Optimisation (62,7%)
	Research & Innovation (54,5%)	Design (60,8%)
Digital	Digital data analysis (AI/ ML ...) (70,5%)	Digital data analysis (AI / ML ...) (64,7%)
	Digital data management (big data, statistics) (56,8%)	Digital data management (big data, statistics...) (62,7%)
	Ability to think 3D (27,3%)	Ability to think 3D (58,8%)
Entrepreneurial	Identify needs and challenging opportunities to create value (68%)	Identify needs and challenging opportunities to create value (78,4%)
	Develop creative and purposeful ideas/solutions (58%)	Develop creative and purposeful ideas/solutions (70,6%)
	Learn through experience (50%)	Work with others (54,9%)
Green	Reuse/recycling AM materials and products (70,5%)	Reuse/recycling AM materials and products (70,6%)
	Life cycle analysis (LCA) (63,4%)	Life cycle analysis (LCA) (56,9%)
	Resource efficiency management (44,3%)	Resource efficiency management (43,1%)

Summing up and to conclude with, no significant differences were observed in the relevance of skills needs within one year timeframe when comparing the priorities of the workforce and companies. When it comes to digital, entrepreneurial and green skills it can be said that workers and companies have exactly the same priorities (except for the third skill in the entrepreneurial domain). In the case of technological skills, bigger differences were observed, and even if both workers and companies have shown interest on process and design/simulation related skills, workers prioritize others like certification & qualification and research & innovation.

6. Conclusions

From the analysis detailed in this report, it is possible to conclude about the evolution of industry needs from 2020 to 2023, as well, on the SAM forecast prediction capability.

The evolution of skills needs priorities identified by industry in the different rounds of the surveys held from 2020 to 2023 was compared for both workers and companies. The comparison of workers results is summarized in Table 3 and the ones for companies in Table 4.

Table 3. Evolution of skills needs priorities of workers.

	TOP 3 SKILLS		
	2020	2022	2023
Technological	AM processes (63,7%)	AM processes (55,4%)	Certification & Qualification (62,5%)
	Material analysis & characterization (43,4%)	Simulation (55,4%)	Simulation (55,7%)
	AM applications (42,5%)	Topology optimization (51,8%)	Research & Innovation (54,5%)
Digital	Ability to think in 3D (45,5%)	Digital data analysis (AI/ ML ...) (64,3%)	Digital data analysis (AI/ ML ...) (70,5%)
	Digital data management (big data, statistics...) (14,3%)	Digital data management (big data, statistics) (53,6%)	Digital data management (big data, statistics) (56,8%)
	Digital data analysis (AI, ML ...) (13,4%)	Ability to think 3D (35,7%)	Ability to think 3D (27,3%)
Entrepreneurial	Learning through experience (60,2%)	Identify needs and challenging opportunities to create value (60,7%)	Identify needs and challenging opportunities to create value (68%)
	Working with others (46%)	Develop creative and purposeful ideas/solutions (55,4%)	Develop creative and purposeful ideas/solutions (58%)
	Motivation & Perseverance (44,2%)	Visualize future scenarios to help guide effort and action (51,8%)	Learn through experience (50%)
Green	Circular economy (18,8%)	Reuse/recycling AM materials and products (69,5%)	Reuse/recycling AM materials and products (70,5%)
	Life Cycle Analysis (LCA) (15,2%)	Life cycle analysis (LCA) (60,7%)	Life cycle analysis (LCA) (63,4%)
	Green awareness (13,4%)	Resource efficiency management (30,4%)	Resource efficiency management (44,3%)

Table 4. Evolution of skills needs priorities for companies.

	TOP 3 SKILLS		
	2020	2022	2023
Technological	AM Processes (70,8%)	AM Processes (52,7%)	AM Processes (70,6%)
	Design (41,7%)	Design (45,5%)	Numerical Modelling / Topology Optimisation (62,7%)
	Post-processing (37,5%)	Numerical Modelling/Topology Optimisation (43,6%)	Design (60,8%)
Digital	Ability to think in 3D (46,2%)	Ability to think 3D (72,7%)	Digital data analysis (AI / ML ...) (64,7%)
	Digital data analysis (AI / ML ...) (30,8%)	Digital data analysis (AI / ML ...) (63,6%)	Digital data management (big data, statistics...) (62,7%)
	Digital data management (big data, statistics...) (26,9%)	Digital data management (big data, statistics...) (63,6%)	Ability to think 3D (58,8%)
Entrepreneurial	Creativity (43,5%)	Identify needs and challenging opportunities to create value (85,5%)	Identify needs and challenging opportunities to create value (78,4%)
	Vision (43,5%)	Develop creative and purposeful ideas/solutions (74,5%)	Develop creative and purposeful ideas/solutions (70,6%)
	Taking the initiative (39,1%)	Learn through experience (60%)	Work with others (54,9%)
Green	Green awareness (34,8%)	Reuse/recycling AM materials and products (74,5%)	Reuse/recycling AM materials and products (70,6%)
	Eco-design (30,4%)	Resource efficiency management (58,2%)	Life cycle analysis (LCA) (56,9%)
	Green resources (30,4%)	Life cycle analysis (LCA) (58,2%)	Resource efficiency management (43,1%)

Overall, some changes can be observed in the skills needs throughout these 3 years. Something to stand out is that from 2022 the needs of both workforce and companies do not seem to show big trend changes, differences are more remarkable in the first period (2020-2022) of this 3-year timeframe. In the case of digital skills, no big changes were observed in the priorities of workforce and companies during the whole timeframe (2020-2023). However, it can be observed that digital skills are gaining interest as a bigger percentage of participants consider those skills as relevant. A similar trend can be seen for green skills when it comes to growing interest of respondents.

Participants taking part in the surveys were also asked to estimate the skills needs within a 3-year timeframe in the first round that took place in 2020. These responses were compared to the ones obtained in 2023 to see the prediction capability of the approach.

Table 5. Prediction of skills needs, three-year scenario.

	TOP 3 SKILLS	
	2020 Future relevance (3Y)	2023 Present relevance
Technological	AM Processes (73,5%)	Certification & Qualification (62,5%)
	AM Applications (55,8%)	Simulation (55,7%)
	Material analysis & characterization (49,6%)	Research & Innovation (54,5%)
Digital	Ability to think 3D (52,7%)	Digital data analysis (AI/ ML ...) (70,5%)
	Digital data analysis (AI/ ML ...) (39,3%)	Digital data management (big data, statistics) (56,8%)
	Digital data management (big data, statistics) (35,7%)	Ability to think 3D (27,3%)
Entrepreneurial	Learning through experience (59,3%)	Identify needs and challenging opportunities to create value (68%)
	Working with others (56,6%)	Develop creative and purposeful ideas/solutions (58%)
	Vision (56,6%)	Learn through experience (50%)
Green	Resource efficiency management (42,9%)	Reuse/recycling AM materials and products (70,5%)
	Circular economy (42%)	Life cycle analysis (LCA) (63,4%)
	Green awareness (35,7%)	Resource efficiency management (44,3%)

From Table 5 it can be concluded that overall differences are not significant between three-year prediction drawn in 2020 (for 2023) and the real case scenario in 2023. In the digital domain, the skills potentially identified as more relevant in 2020 are the same that the ones selected also in 2023. As for the entrepreneurial skills, the selected ones in 2020 and three years later are not equal, but could be considered as similar ("vision" could be considered equivalent to "identify needs and challenging opportunities to create value"). In the case of green skills, the ones considered as more relevant in 2023 are also related to the predicted ones in 2020. Indeed, actual skills, which are more specific, could be considered within the skills (as they are more general) predicted in 2020. The difference is more noteworthy in the technological domain, where the prediction from 2020 does not match with the real case scenario of 2023.From the analysis detailed in this report, the following conclusions have been drawn:

- *STABILITY OF REQUIRED SKILLS/ TECHNOLOGY MATURITY* Priorities from workforce and companies do not seem to change significantly especially in the last year. This could be an indicator to conclude that AM technology is not evolving as quickly as thought.
- *DIGITAL SKILLS NEEDED* A growing interest of industrial companies and workforce for digital skills was identified from the survey results. Conclusions obtained for these skills could be influenced by the list of potential answers, but in the validation workshop experts were asked to list some relevant digital skill; some of those were: programming, data for process monitoring, AI, machine learning and data handling, management & analysis.
- *ADEQUATE PREDICTION FOR SKILLS CATEGORIES* The prediction capability of the yearly survey method seems to be adequate overall. No significant changes were observed when comparing future 3-year scenario (2020) with present scenario (2023).

- *DETAILED DATA ANALYSIS* The analysis of the survey results was performed in general terms considering all the answers regardless the country or the manufacturing process of the respondents. It is true that the development of AM market could differ from one country to another or from a technology to another and therefore the skills needs could vary accordingly. However, as the number of results obtained is limited and as most of them belong to a certain country or manufacturing technology, it is difficult to extract conclusions due to the low representativeness of the data. Even if this was not possible now, it would be advisable to continue this analysis in the future.

7. Annexes

7.1 List of partners attending the 4th AM Skills Needs Analysis Workshop

1. Adelaide Almeida (EWF)
2. Begum Canaslan (FA)
3. Ilka Zajons (LAK)
4. Henning Ahlers (LAK)
5. Yvonne Johannsen (LAK)
6. David Wimpenny (MTC)
7. Eujin Pei (UBRUN)
8. Panagis FOTEINOPOULOS (LMS)
9. Borzoo (EC Nantes)
10. Pedro Alvarez (LORTEK)
11. Michel Janssens (Materialise)
12. Colin Meade (IMR)
13. Tamara Wierks (IMR)
14. Paula Queipo Rodríguez (IDONIAL)
15. Tânia S. Avelino (ISQ)
16. Bianca Maria Colosimo (POLIMI)

7.2 Agenda for the 4th AM Skills Needs Analysis Workshop

4th INTERNAL WORKSHOP DATA ANALYSIS & VALIDATION OF SKILLS NEEDS– 5.4.2023

Time		
14.00h CET	Agenda & session aim Overview on last round of Real Case Scenario Surveys among industry Overview on Recruitment agencies Survey 2023	Adelaide, EWF
14.20-15.00	Group analysis of Companies replies (55 answers) according to core reflection questions	Group 1
	Group analysis of Workforce replies (102 answers) according to core reflection questions	Group 2
15.00-15.20	Key findings of Companies real case needs 2023 (comparison with 2022 data – Real Case & Short term)	Group 1 Rapporteur
15.20-15.40	Key findings of Workforce real case needs 2023 (comparison with 2022 – Current /real case needs 2022)	Group 2 Rapporteur
15.40- 16.00	Wrap up : - Data to be further explored & validated with external organisations - Implications for IAMQS - Next actions	Pedro Alvarez, LORTEK

7.3 Agenda for the 4th AM Skills Needs Validation Workshop

4th WORKSHOP FOR VALIDATION OF SKILLS NEEDS– 27.4.2023

9.00	**Welcome and opening**	
4th WORKSHOP FOR VALIDATION OF SKILLS NEEDS **SAM Project & Emergent AM Skills Needs**		
9.15	*AM education and training framework: IAMQS system*	Eurico Assuncao (EWF)
9.30	Industrial Skills Needs (latest findings)	Jon Aranzabe (Lortek) Adelaide Almeida (EWF) Rita Bola (EWF)
11.00-11-15	***Coffe break***	
11.15	*Role of the IAMQS in addressing the skills needs of AM companies*	Michel Janssens (Materialise)
11.45	*AM Sector Skills Strategy Roadmap - Recommendations for industrial organizations*	Adelaide Almeida (EWF) *Paula Queipo (IDONIAL)*
12.15-13.15	**Networking Lunch**	

7.4 List of organizations attending the 4th AM Skills Needs Validation Workshop

3DHUB	Institut Químic de Sarrià (IQS)
AO Research Institute Davos	IQS
ASTM International	ISQ
Atlas Copco	KU Leuven
Belgian Defense	Lancaster University
Brainport Development	Laser Zentrum Hannover e.V.
CECIMO	LMS
CETIM	Lortek
cirp GmbH	Materialise
Danish AM Hub	Moduleworks
Danish Technological Institute	Siemens AG
DTI	SINTEF Manufacturing AS
EDA	Technical University of Munich - Professorship of Laser-based Additive Manufacturing
ESRF	Technifutur
European Commission	The European Research Executive Agency (REA)
EWF	TU Eindhoven
FAN3D	Z3Dlabs bv
Fraunhofer Institute for Production Technology IPT	Zurich University of Applies Science, Institute of Product Development and Production Technologies
IDEA Consult	
IDONIAL	
IMR	
INEGI	

7.5 Definitions and list of skills by category

Categories of skills used in SAM

Four categories of skills are addressed in SAM project analysis, namely: technological, green, digital and entrepreneurial.

Technological skills

"Technological Skills" are defined as "Ability to apply knowledge and use know-how to compete tasks and solve problems" [within specific activities]" (Adapted from CEDEFOP 2008).

https://www.cedefop.europa.eu/en/projects/validation-non-formal-and-informal-learning/european-inventory/european-inventory-glossary#S

Examples of Additive Manufacturing related skills: AM processes; Numerical modelling; Simulation; CAPP (Computer Aided Process Planning) for AM; Topology optimization; Design for AM; Structural integrity; Materials analysis and characterization; Pre-processing & material handling; post-processing, etc.

*Source: AM experts were consulted to identify the list of technological skills in AM. The list is not closed and required further exploitation in order to detect sector and /or profile specific ones.

Digital skills

"Digital Skills" are defined as "range of abilities to use digital devices, communication applications, and networks to access and manage information. They enable people to create and share digital content, communicate and collaborate, and solve problems for effective and creative self-fulfillment in life, learning, work, and social activities at large" (UNESCO, 2022).

https://www.unesco.org/en/articles/digital-skills-critical-jobs-and-social-inclusion

Examples of Additive Manufacturing related skills: Digital data analytics (Artificial intelligence, Machine learning); Digital data management (big data, statistics…); Ability to think in 3D; Cybersecurity; Coding / programming.

*Source: AM experts were consulted to identify the list of digital skills in AM. Later on, the DiGComp was used for further exploitation in alignment with AM specific sector ones.

Entrepreneurial skills

"Entrepreneurship or Entrepreneurial skills" are defined as "transversal key competence applicable by individuals and groups, including existing organizations, across all spheres of life" or "when you act upon opportunities and ideas and transform them into value for others." The value that is created can be financial, cultural, or social." (ENTRECOMP, 2016)

https://joint-research-centre.ec.europa.eu/entrecomp-entrepreneurship-competence-framework_en

Examples of Additive Manufacturing related skills: communication; teamwork, costumer handling, problem solving, learning, and planning and organization; Spotting opportunities; Creativity; Valuing ideas; Self-awareness and self-efficacy; etc.

Source: The EntreCOMP framework was used as reference in combination with transversal skills reference in Skills Intelligence tool.

Green skills

"Green skills" are defined as "knowledge, abilities, values and attitudes needed to live in, develop and support a sustainable and resource-efficient society (CEDEFOP, 2015)

https://www.unido.org/stories/what-are-green-skills,

Examples of Additive Manufacturing related skills: resource efficiency, green awareness, Life Cycle Assessment (LCA), eco-design, circular economy, green resources and green products.

Source: The categorization into AM Green skills was based on the CEDEFOP Publication "Green skills and innovation for inclusive growth".

https://www.cedefop.europa.eu/en/publications/3069