

Address FOR FUTURE



WP4: Mapping

Result 3. Skill Mapping for Additive Manufacturing

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1. INTRODUCTION

The objective of this work package within the project was to develop a comprehensive skill map for additive manufacturing (AM) and assess the status of the industry through benchmark studies conducted with expert companies specializing in AM applications.

To achieve this objective, several activities were outlined in the project. The first activity involved extensive research and data collection, where an in-depth study of the existing literature, reports, and resources related to AM was conducted.

The second activity revolved around engaging with expert companies in the field of AM. These companies, known for their expertise and experience, were engaged with to provide invaluable insights into the current practices, challenges, and opportunities within the industry. Through interviews/workshops, surveys, and on-site visits, their practices were benchmarked against industry standards, and best practices and potential areas for improvement were identified.

Another important aspect of the project was the development of a skill map for AM. This map provided a visual representation of the required competencies and skill needed for different roles within the AM industry. The knowledge areas, technical skills, and soft skills that were crucial for success in this field were outlined in the skill map.

Overall, the objective of this work package was to prepare a comprehensive skill map for additive manufacturing and assess the status of the industry through benchmark studies conducted with expert companies. The research was conducted, expert companies were engaged with, and a skill map was developed, contributing to the advancement and growth of the AM industry by identifying areas for improvement and supporting the development of a skilled and knowledgeable workforce.

2. AIM

The aim of the additive manufacturing skill mapping activity is to develop a comprehensive skill map for additive manufacturing (AM) by evaluating the status of the industry, identifying skill requirements, knowledge gaps, and technological advancements.

Additionally, this workpackage, aims to conduct benchmark studies with expert companies in the field of AM applications to gain insights into best practices and industry trends.

The ultimate goal is to provide a roadmap for individuals, educational institutions, and organizations to effectively develop and enhance their capabilities in the field of AM.

3. SCOPE

The scope of this work package encompasses various activities aimed at developing a comprehensive skill map for additive manufacturing (AM) and conducting benchmark studies with expert companies in the field of AM applications. The project will focus on evaluating the status of the industry, identifying skill requirements, knowledge gaps, and technological advancements within AM.

3.1. The Scope of Activities

1. Extensive Research and Data Collection:

Conducting thorough research and data collection to gather relevant information, literature, reports, and resources related to AM.

2. Engagement with Expert Companies:

Engaging with expert companies that specialize in AM applications to gain insights into their practices, challenges, and opportunities. This will involve conducting interviews/workshops, surveys, and on-site visits to benchmark their practices against industry standards and identify best practices and areas for improvement.

3. Skill Mapping:

Developing a skill map that visually represents the required competencies and skills for different roles within the AM industry. This will outline the knowledge areas, technical skills, and soft skills necessary for success in the field of AM.

4. Assessment of Industry Status:

Evaluating the current state of the AM industry by analyzing the data collected from research and benchmark studies.

5. Recommendations and Guidance:

Providing recommendations and guidance based on the findings of the project to support the growth and advancement of the AM industry. This may include suggestions for skill development programs, educational initiatives, and industry-wide collaborations.

4. METHODOLOGY

The methodology for this project involves survey and conducting visits or online interviews with additive manufacturing (AM) expert companies to collect benchmark information.

Skill maps are generally conducted in many sectors, but relative comparisons between skills and behavioral competencies can be neglected. For this reason, Address for Future project has taken great care to work with experts in each field. In this context, 2 Human Resources (HR)

professionals with over 20 years of technical competency experience in the HR field have also participated in the skill map study as in kind contribution of Project Coordinator. These HR professionals have guided and moderated the team with their long years of industrial HR experience throughout the work package. They have also provided important insights into behavioral skills that are often underestimated in technical roles. The HR Experts and ADDRESS Project team collected comprehensive data related to various aspects of AM, including roles and responsibilities of individuals, required competencies, available competencies, current development activities, and current and future needs and expectations within the industry. The collected data summarized and utilized to prepare a skill map for AM.

4.1. The methodology of Skill Mapping

1. Identification of AM Expert Companies:

HR Experts and ADDRESS Project team identified a set of AM expert companies based on their reputation, expertise, and industry recognition. These companies selected to ensure diversity in terms of industry sectors, geographic locations, and company sizes.

2. Visit or Online Interview Planning:

HR Experts and ADDRESS Project team reached out to the identified AM expert companies to schedule workshops/visits or online interviews. Profiles of companies from different countries in Europe with diverse areas of expertise were selected. Partners participated in the organization of these activities. Meetings were organized with companies from various sectors such as machinery manufacturers, engine manufacturers in the defense industry, service providers, and the automotive sector. The mode of interaction, whether physical visits or online interviews, determined based on the availability and preferences of the participating companies.

3. Data Collection:

During the workshop/visits or online interviews, HR Experts and ADDRESS Project team collected relevant information pertaining to AM.

HR Experts and ADDRESS Project team engaged with key personnel, including managers, engineers, technicians, and other relevant stakeholders within the companies.

The collected data covered a range of topics, including roles and responsibilities of individuals, required competencies in general, available competencies within the company, ongoing development activities, and current and future needs and expectations related to AM.

4. Data Summarization and Analysis:

The collected data organized and summarized by the HR Experts as key insights, trends, and patterns identified through analysis. The team paid particular attention to common skill requirements, competency gaps, and emerging trends within the AM industry.

5. Skill Map Development:

Based on the analyzed data, HR Experts and ADDRESS Project team developed a skill map for AM. The skill map did visually represent the required competencies and skills for different roles within the AM industry.

It provided an overview of the knowledge areas, technical skills, and soft skills that are essential for success in the field of AM.

6. Finalization of the Skill Map:

HR Experts and project team developed skill map based on the feedback received and the project objectives.

The skill map refined and presented in a comprehensive and user-friendly format, ready for dissemination and utilization.

4.2. Preparations of Benchmark Questions:

The methodology for the preparation of benchmark questions involves a systematic approach to design and develop effective and relevant questions for the benchmarking process. The following steps outline the methodology:

1. Define the Objectives:

The first step is to clearly define the objectives of the benchmarking exercise.

This involves understanding what specific insights or information the benchmarking process aims to gather.

2. Identify Key Areas of Focus:

Once the objectives are defined, identify the key areas of focus or topics that will be covered in the benchmarking process. These areas may include performance metrics, best practices, industry trends, operational processes, or any other relevant aspects.

3. Conduct Background Research:

Conduct thorough background research to gather information on the topic or areas of focus. This research will help in understanding the context, industry standards, and existing practices related to the benchmarking areas.

4. Determine the Target Audience:

Identify the specific target audience for the benchmarking questions. This could include internal stakeholders within the project or external companies or experts in the field.

5. Collaborate with Partners:

Collaborate with partners involved in the benchmarking process to gather their insights and inputs. Partners can provide valuable expertise and knowledge related to the benchmarking areas and help in shaping the questions.

6. Design the Questionnaire:

Based on the objectives, areas of focus, research findings, and input from partners, design a structured questionnaire. The questionnaire should consist of well-crafted questions that are clear, concise, and relevant to the benchmarking objectives.

7. Use Different Question Types:

Utilize a variety of question types to gather comprehensive data. This may include multiple-choice questions, open-ended questions, Likert scale ratings, ranking questions, or qualitative prompts.

8. Consider Benchmarking Best Practices:

Consider best practices in benchmarking question design, such as using standardized scales or providing clear instructions. Ensure that the questions are unbiased, avoid leading or suggestive language, and are appropriate for the target audience.

9. Pilot Testing and Refinement:

Conduct a pilot test of the questionnaire with a small sample group to identify any potential issues or areas for improvement. Based on the feedback received, refine and finalize the benchmarking question

10. Documentation and Distribution:

Document the final set of benchmarking questions along with any relevant instructions or guidelines. Distribute the questionnaire to the target audience, whether it is internal stakeholders or external companies, using appropriate channels.

Key questions to be answered:

- What are the main roles in AM today and for the future?
- What are the key tasks of the determined roles?
- What is the required skill to perform respective tasks?
- What are benchmarks in industry doing?
- What are the capabilities and gaps in the industry?

Key Activities:

- Benchmarking with companies with high level AM standards
- Defining main roles and task description to perform the job
- Determination of required critical skills for each role
- Gathering inputs about skill matrix from stakeholders
- Determination of required skill level for each competency

Throughout the methodology, it is important to ensure that the workshop/benchmarking questions are aligned with the objectives of the benchmarking exercise, capture the necessary information, and provide valuable insights for the benchmarking process. Throughout this work package, efficiency has been enhanced by collaborating with partners and taking into account the dynamics in different countries to ensure the understanding of these questions and obtaining responses. These are some of main topics for the answers and the activities:

Besides, there are other questions in each workshop activity. The whole question checklist is seen below;

1. How long is your organisation using AM?
2. What is your sector ?
3. Which AM technologies do you use in your organisation?
4. Which roles do you have in AM area?
5. How is the general workflow for AM, connection between the roles ?
6. What are the general responsibilities for each role?
7. For each role repetitive daily routine tasks?
8. For each role , tasks at regular intervals (weekly, monthly...)?
9. For each role; what is the required education (vocational highschool, BsC,Master,PhD...)?
10. For each role; what is the required experience (0-1 year, 1-3 years, 3-5 years, or more than 5 years)?
11. How many associates do you have in each role?
12. For each role, what are the performance indicators?
13. For each role; what is the pre requisite technical / methodical skills,competencies?
14. For each role; what is the unique (differentiative) behavioral skills,competencies?
15. If you transfer one associate from different department to AM area , what are the prerequisites?
16. What do you need to develop AM associates as priority?
17. what kind of development activities , trainings for AM associates do you have currently?
18. Whats is your technology roadmapping in AM (5 years/10 years)
19. Will you need different roles in AM area in the future ?
20. What would be your future needs to develop AM associates?

4.3. Workshops/Benchmarking with AM Companies:

For the benchmarking process, a total of 11 companies were selected from various industries to gather insights and information related to additive manufacturing (AM).

These companies include TEI, TAI, and Roketsan from the aerospace and defense industry, Coşkunöz Metal Form and Mahle Global from the automotive supplier sector, Infotron and Artı 90 from engineering and prototype manufacturing, Hidromek from construction machinery, Signova and Meltio from Manufacturing industry, and Caracol from robotics industry.

In addition to the company representatives, the benchmarking process involved over 50 participants who held various job roles, including job holders, supervisors, and managers within these companies. Academic advisors from universities and consultants also contributed their expertise to the benchmarking activities.

The benchmarking process aimed to collect valuable insights and data on AM practices, challenges, trends, and best practices from these participating companies.

4.4. On-Site Visits:

The benchmarking team visited and also did online meetings with each company to observe their AM operations firsthand. They interacted with employees, including job holders, supervisor, managers and academic advisors to gain insights into their roles, responsibilities and experiences with AM.

4.5. Interviews and Surveys:

1. Interviews:

Interviews were conducted with key personnel, including managers, supervisors, and consultants, to gather in-depth information about AM implementation, challenges faced, and lessons learned.

The benchmarking process provided valuable information on the AM practices and experiences of the participating companies. It helped identify successful strategies, areas for improvement, and emerging trends within the AM industry. The insights gained from this process supported the enhancement of AM implementation and contributed to the overall growth and advancement of additive manufacturing in various industries.

Below, companies that were interviewed based on the identified roles are marked in green.

1 Main Roles	<u>Coşkunöz</u>	TAI	Roketsan	TEI	<u>Infotron</u>	Artı 90	Hidromek	Mahle	<u>Signova Meltio</u>	Caracol
Design Engineer										
Structural Analysis / Simulation Engineer										
Application / Process Engineer										
Operator (machine-post process-quality)										
Leadership Role										

2. Skill Map Survey

Within the scope of the Skill Mapping work package, a survey has been developed to gather valuable insights from the stakeholders. The aim of this survey is to assess and evaluate the identified qualifications and skills from both a technical and soft skills perspective which has been taken from the benchmarking and on-site visits. Basically, a verification was requested

from the participants for the roles that emerged in the benchmark and on-site visits and the competencies that were stated to be critical based on these roles. The purpose here is actually to verify basic skill mapping study so that in the next package, we can concentrate on the most important topics for the training program as the competencies.

For this, the competencies were asked to be ranked relatively with sending surveys to 2.000 contacts. The participants are asked to provide their ratings and assessments based on their expertise and experience in the field of Additive Manufacturing (AM).

The collected responses from the survey will serve as valuable inputs for the further development of the training curriculum. By analyzing the ratings and evaluations, the project partners will be able to identify the key areas of focus, prioritize specific skills, and determine the proficiency levels required for each qualification which will play a crucial role in shaping the structure and content of the training programs.

A total of 71 respondents participated in the survey, providing valuable insights into the roles, types of organizations, and the importance of various competencies.

Survey Methodology:

The survey was distributed to a diverse range of organizations involved in the field of additive manufacturing. Participants were asked to rank the requirements based on their relevance and importance to the ADDRESS Project curriculum. The survey took into account the perspectives of educational institutions, manufacturers, and service providers. Participants include the EU's largest and the world's leading research centres, universities and high-tech companies.

Role within the Organization:

The survey asked respondents to indicate their role within the organization. The distribution of roles is as follows:

Title	Percentage	Number of Participants
Manager	33,80%	24
Engineer	23,94%	17
Operator	0,00%	
C-level	5,63%	4
Other (please specify)	36,62%	26

The majority of respondents identified themselves as managers, followed by others who are generally scientific experts, research specialists.

Type of Organization:

Respondents were asked to select the type of organization they belong to. The distribution of organization types is as follows:

Type of Organization	Percentage	Number of Participants
Start-up	5,63%	4
SME	14,08%	10
Large Company	29,58%	21
Industrial Association	1,41%	1
Education	23,94%	17
Private Education	2,82%	2
Organization/Institute	11,27%	8
Technology Center	4,23%	3
Research Institution	7,04%	5

The survey shows that the majority of respondents belong to large companies, followed by educational institutions. It is interesting to note the presence of start-ups and organizations representing industrial associations.

General Competencies for Additive Manufacturing:

Respondents were asked to rank the general competencies they believe individuals working in additive manufacturing within their company should possess. The competencies and their corresponding scores are as follows:

Competency Name	Ranking
AM fundamentals	16,42
AM Process Overview	15,90
Material Knowledge	15,22
AM Manufacturing Technologies	15,19
Conventional manufacturing technologies	13,25
Computer aided design (CAD)	12,19
AM international quality standards	9,78
Computer aided manufacturing (CAM)	9,73
Design for related processes	8,92
Post process skills	8,73
Computer aided engineering (CAE)	8,56
Production using AM based processes (LPBF, Binder Jetting, DED, etc.)	7,93
Sustainability in AM	7,83
Safety knowledge	7,78
Design software	7,44
Quality testing and evaluation methods	7,24
Engineering analysis principles for related processes	6,81
Maintenance (TPM)	6,19
Analysis software	4,90

The survey indicates that respondents consider a strong understanding of AM fundamentals and process overview to be highly important. AM manufacturing technologies and material knowledge also received significant importance in the rankings.

Soft Skill Competencies for Additive Manufacturing:

Respondents were asked to rank the soft skill competencies they believe individuals working in additive manufacturing should possess. The competencies and their corresponding scores are as follows:

Competency Name	Ranking
Design Thinking	7,52
Creative thinking (out of box thinking)	6,16
Critical thinking	6,05
Process control and quality assurance methods	5,64
Curiosity	5,53
Teamwork	5,38
Eagerness to learn	4,93
Initiative (risk taking and decision making)	4,90
Production economics and business economics	4,74
Project management methods	4,16

According to the survey results, design thinking was identified as the most important soft skill competency for individuals working in additive manufacturing. Critical thinking, creative thinking, process control and quality assurance methods, and curiosity were also ranked as significant competencies.

Conclusion:

The Skill Map Survey conducted at ADDRESS provides valuable insights into the roles, types of organizations, and the importance of various competencies within the field of additive manufacturing. The findings highlight the significance of having a strong understanding of AM fundamentals, process overview, and manufacturing technologies. Additionally, soft skills such

as design thinking, critical thinking, and creative thinking were recognized as essential for individuals working in additive manufacturing.

4.6. Collecting Data and Creating Report

As a result of interviews, on-site visit and benchmarking, 4 main roles were determined as common in all sectors. These are Designer, Process Engineer, Simulation Engineer, and Operator roles.

The skill map study showed that contrary to the conventional production techniques, there is **no great divergence in the job descriptions and competencies of the engineers working in the AM field. The defined technical, methodical, competencies largely overlapped in all engineering roles.**

Alongside this, **different expectations regarding behavioral competencies have been observed.** This result may reveal **new dynamics of engineering.** A holistic perspective and competencies that can start with abstract thinking and foresee the process from all perspectives are the essential requirements of AM engineers.

This could have significant implications for hiring practices, training programs, and workforce development strategies. Since some personal traits and behavioral competencies are the most differentiated competencies, especially for designers and process engineers, they should be evaluated during the hiring process.

Therefore, while giving technical education, it is necessary to use training methods that stimulate methodical and behavioral competencies.

5. KEY FINDINGS

Differences and Similarities between Conventional Manufacturing and Additive Manufacturing:

Conventional manufacturing and additive manufacturing (AM) differ in several key aspects. Conventional manufacturing techniques typically involve subtractive processes, where material is removed from a larger piece to achieve the desired shape. On the other hand, AM utilizes additive processes, building objects layer by layer using 3D printing technologies. This fundamental difference in manufacturing techniques requires a shift in mindset and understanding of the unique capabilities and limitations of AM.

Differentiated competencies come into play, particularly for roles like designers and process engineers in AM. While personal traits and behavioral competencies are important in both conventional manufacturing and AM, individuals involved in AM must think creatively, adapt to new technologies and processes, and possess a strong problem-solving mindset. The dynamic nature of AM and the need for innovation and adaptability necessitate these differentiated competencies.

Overall, the differences between conventional manufacturing and AM encompass manufacturing techniques, cost estimation, sustainability considerations, practical training, and the required competencies. Understanding these distinctions is essential for organizations to harness the full potential of AM and make informed decisions about integrating it into their manufacturing processes.

5.1. Using the Findings in Building AM Skills:

The findings regarding the differences and similarities between conventional manufacturing and AM provide valuable insights for building AM skills. The knowledge and wide range of experience in conventional manufacturing techniques serve as a strong foundation for understanding the principles and practices of AM.

To develop AM skills effectively, individuals should:

- 1. Embrace the Differences:**

Recognize and understand the unique aspects of AM, such as its additive nature and the design possibilities it offers.

- 2. Expand Commercial Knowledge:**

Gain a comprehensive understanding of the cost estimation process in AM, considering factors like material costs, post-processing, and testing.

- 3. Explore Sustainability Aspects:**

Deepen knowledge about the sustainability benefits of AM and identify business cases where AM can contribute to sustainable manufacturing.

- 4. Engage in Practical Training:**

Participate in hands-on training programs specific to AM technologies, materials, and best practices.

This hands-on experience will help individuals identify the optimal use of AM in their respective fields.

- 5. Foster Differentiated Competencies:**

Focus on personal traits and behavioral competencies, such as creativity, adaptability, and problem-solving skills, to thrive in the unique challenges and opportunities presented by AM.

By leveraging the findings and recommendations, individuals can effectively bridge the gap between conventional manufacturing and AM, acquiring the necessary skills and knowledge to succeed in the additive manufacturing industry.

But the biggest differences between conventional and additive manufacturing skill map; **personal traits and behavioral competencies.**

Personal traits and behavioral competencies are indeed crucial differentiators, particularly for roles such as designers and process engineers in the additive manufacturing (AM) field.

While technical knowledge and skills are essential, it is the combination of personal traits and behavioral competencies that truly sets individuals apart in the AM industry.

Designers working with AM technologies need to possess a high level of creativity and innovative thinking. They must be able to envision and develop designs that fully utilize the unique capabilities of AM, pushing the boundaries of what is traditionally possible in manufacturing. Additionally, designers should demonstrate adaptability and flexibility in adapting their designs to different AM processes, materials, and constraints.

Process engineers in AM must possess a strong problem-solving mindset and the ability to troubleshoot complex manufacturing challenges. They need to be proactive and analytical in identifying and addressing issues that may arise during the AM process. Furthermore, process engineers should have excellent communication and collaboration skills to work effectively with cross-functional teams and stakeholders, translating design requirements into feasible AM processes.

Both designers and process engineers in AM must exhibit a willingness to learn and continuously update their skills as new technologies and materials emerge. They should be open to experimentation and comfortable with taking calculated risks to explore innovative solutions in the rapidly evolving field of AM.

In summary, personal traits and behavioral competencies play a significant role in differentiating designers and process engineers in the AM industry. These competencies, when combined with technical expertise, contribute to the successful implementation of AM technologies and the advancement of additive manufacturing as a whole.

5.2. Matching of Critical Skills to IAMQS Outcomes

SAM (2019-2022) is Erasmus+ Project about Sector Skills Strategy in Additive Manufacturing which aims to tackle the current European need for developing an effective system to identify and anticipate the right skills for the Additive Manufacturing (AM) sector demands in response to the increasing labor market needs, thus, contributing for the smart, sustainable and inclusive growth of the AM sector.

AM competencies within the scope of the SAM project, that was made as a complimentary impact, used as a benchmark in ADDRESS project and the basic set of criteria taken.

In this part of report, the fulfilment of the essential skills identified through the WP4 by the competencies provided by the different levels of the IAMQS is analyzed.

All matching study steps and results have been presented in Appendix 8: Matching of Critical Skills to IAMQS Outcomes. In summary, both projects have their own merits and relevance within the context of additive manufacturing. The first project, SAM Project, ensures

alignment with industry standards and requirements, which is crucial for professionals seeking recognition and employability within the field. The second project, with its beginner, intermediate, and advanced stages, addresses the need for comprehensive curricula that accommodate learners at different skill levels and support their progression within additive manufacturing.

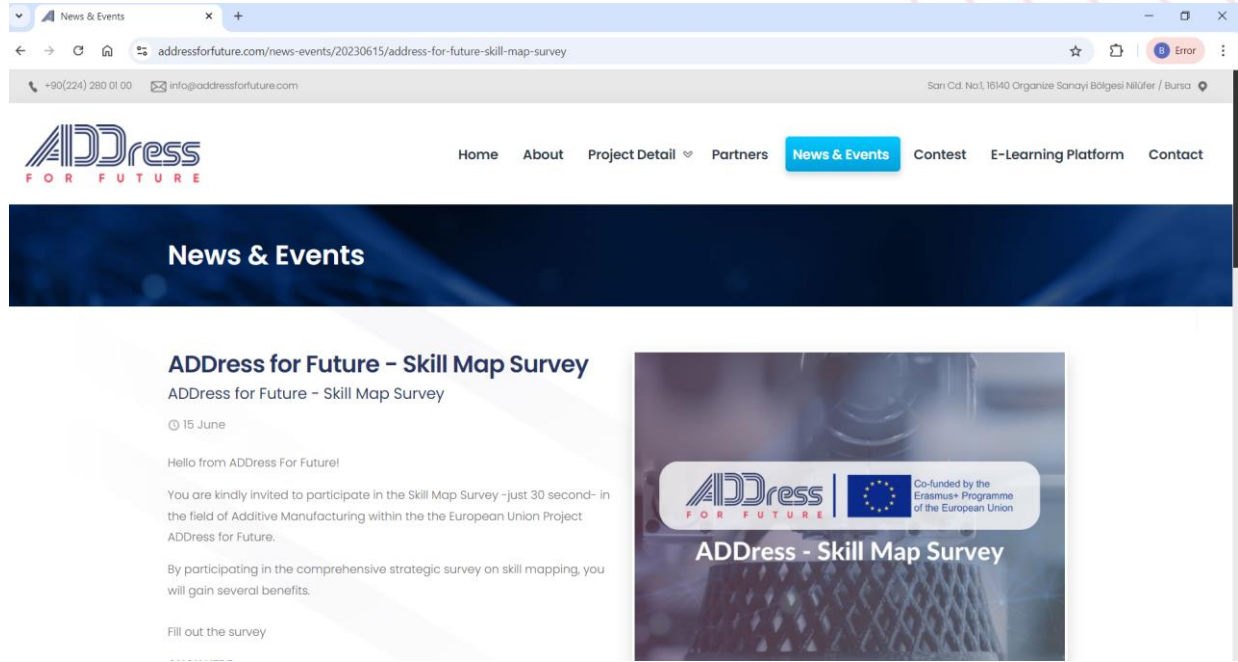
6. DISSEMINATION ACTIVITIES

1. Address for Future Project was introduced at the 25th Welding Conference held in Spain in March 2023. Skill Map work package was also presented in detail within this introduction. The audience was particularly interested in how important behavioral competencies are. In addition, the commercial perspective gained importance among the feedback given. This revealed the need for AM engineers to have a different perspective than conventional production engineers, not only in terms of technical but also feasibility. In this sense, it has also been revealed how critical the entrepreneurial perspective envisaged at the project writing stage is for AM. Similarly, this study has set an example for us in terms of the content that will be featured on the e-learning platform.
2. Survey Study: A total of 71 individuals replied the survey, providing valuable insights into the roles, types of organizations, and the importance of various competencies. Announcements were made on social media, web site, by mailing and one to one meeting for this study, and all partners announced the survey study to their networks as stated below. This provided them with the opportunity to learn about the current project progress and to be reputable in terms of continuing the project with determination, in addition to announcing the project.

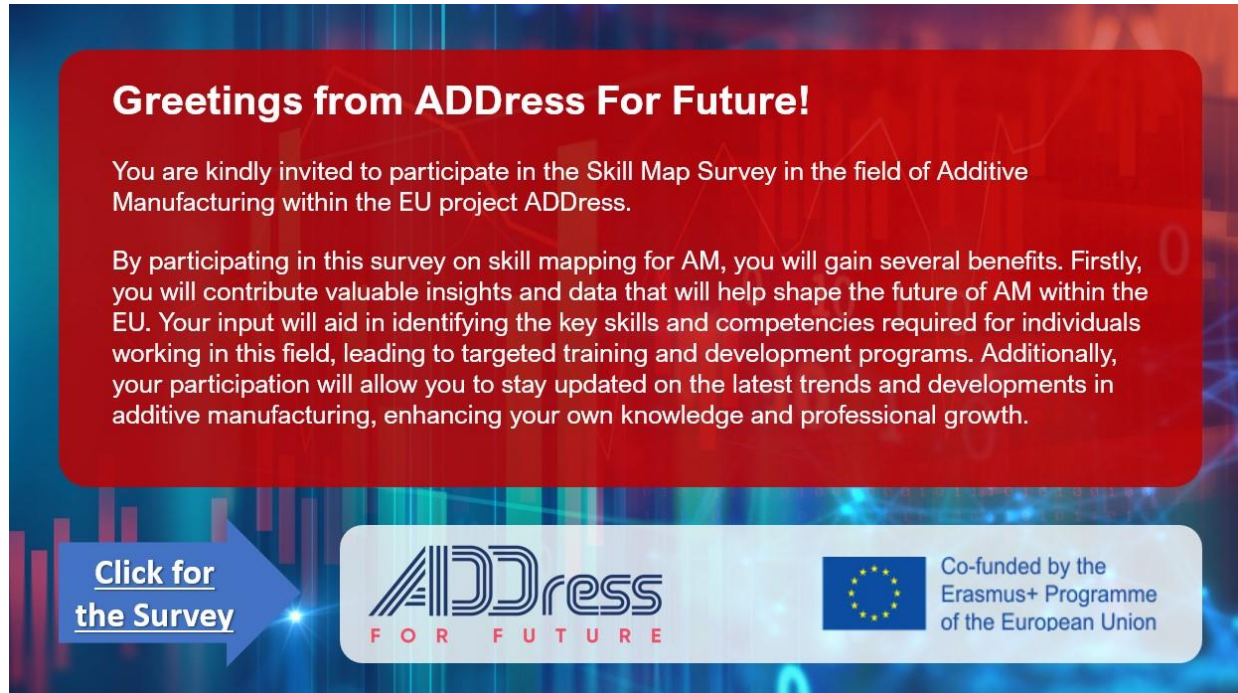
E-Mailing Example:



Web Site Announcement:



Survey Banner:



3. Company Visits: In this work package, some expert companies were determined so that skill map studies could be carried out on the right ground. HR Experts and ADDRESS Project team reached out to the identified AM expert companies to schedule visits or online interviews.

Profiles of companies from different countries in Europe with diverse areas of expertise were selected. Partners participated in the organization of these activities. Meetings were organized with companies from various sectors such as machinery manufacturers, engine manufacturers in the defense industry, service providers, and the automotive sector. The companies visited or interviewed online were as follows: TEI, TAI, and Roketsan from the aerospace and defense industry, Coşkunöz Metal Form and Mahle Global from the automotive supplier sector, Infotron and Artı 90 from engineering and prototype manufacturing, Hidromek from construction machinery, Signova and Meltio from manufacturing industry, and Caracol from robotics industry. The sector experts who listened to the project in detail made proposals to support the studies in terms of testing and exchange of ideas in the platform studies. This shows the importance of company visits in terms of the dissemination and reputation of the project.

4. Technical Teacher Training: Trainers' training was held at Coşkunöz Education Foundation within the scope of the Ministry of National Education Vocational and Technical Education in-service trainings on 19-29 March, 2023. In these trainings, curriculum studies related to additive manufacturing were also conveyed and technical teachers were trained on the prominent competencies.

7. CONCLUSION

In conclusion, skill mapping is a crucial process that helps organizations identify, assess, and manage the skills and competencies of their workforce. It provides valuable insights into the existing skill levels, identifies skill gaps, and enables organizations to develop effective strategies for skill development and talent management.

A skill matrix, also known as a competency matrix, is a tool used to assess and visualize the skills and competencies of individuals or teams within an organization. It provides a structured way to identify the existing skill levels, track skill development, and identify skill gaps that need to be addressed.

The development of skills in additive manufacturing (AM) is vital to harness the full potential of this innovative technology. To cultivate a workforce equipped with the necessary competencies, a multi-faceted approach is required.

Based on the findings and recommendations, the following conclusions can be drawn for skill development in AM:

1. Early Education and Awareness:

Initiating awareness and development activities in elementary or secondary schools can instill an additive mindset in future generations.

Introducing AM concepts and applications at an early stage can nurture curiosity and lay the foundation for future learning.

2. Innovative Teaching Methods:

Incorporating teaching methods that foster creativity and adaptability skills is essential. Integrating interdisciplinary "Science and Art" training in university curricula can encourage a different way of thinking and problem-solving

3. Comprehensive Training Programs:

Training programs should offer a combination of generalist and specialist courses to cater to the diverse needs of individuals entering the AM field.

Modular courses that provide hands-on activities and industry practices enable practical skill development.

4. Holistic Approach to Training:

Training programs should cover not only technical aspects but also softer issues such as quality assurance, sustainability, economics, and business models relevant to AM.

A holistic approach ensures that individuals are equipped with a well-rounded understanding of AM's broader implications.

5. Industry-Academia Partnership:

Collaboration between industry and academia is crucial for bridging the gap between theoretical knowledge and real-world applications.

Partnerships can facilitate the exchange of expertise, resources, and practical insights to align skill development with industry requirements.

6. Community-Based Networking:

Establishing community-based networks within the AM ecosystem fosters continued sharing, learning, and collaboration.

Engaging with industry associations, professional networks, and online communities facilitates knowledge exchange and staying updated on the latest advancements.

As a result of the conducted studies, the address for future skill mapping is presented as Appendix 7 Skill Map which provides a comprehensive overview of the proposed framework and recommendations for the development and implementation of future skill mapping initiatives.

Required Competencies:

General Skills:

- AM Process Overview
- Conventional Manufacturing Technologies
- AM Fundamentals
- Material Knowledge
- AM Manufacturing Technologies
- Computer-Aided Design (CAD)
- Computer-Aided Manufacturing (CAM)
- Computer-Aided Engineering (CAE)
- AM International Quality Standards
- Sustainability in AM
- Maintenance (TPM)
- Post-Process Skills
- Safety Knowledge

Process-based Skills:

- Design for the Related Process (relevant principles)
- Design Software (e.g., SolidWorks, Fusion 360...)
- Engineering Analysis Principles for The Related Process
- Analysis Software
- Production of the Related Process
- Quality Testing and Evaluation Methods

Methodical & Behavioral Skills:

- Design Thinking
- Process Control and Quality Assurance Methods
- Production Economics and Business Economics
- Project Management Methods
- Critical Thinking
- Curiosity
- Eagerness to Learn
- Creative Thinking (out-of-the-box thinking)
- Initiative (risk-taking and decision-making)
- Teamwork

These required competencies encompass a range of technical, methodical, and behavioral skills necessary for success in additive manufacturing. Developing proficiency in these areas will enable individuals to effectively navigate the complexities of AM processes, contribute to

design optimization, ensure quality control, and make informed decisions within a business and project management context. Moreover, cultivating attributes such as critical thinking, curiosity, and teamwork enhances innovation and collaboration in the AM field. By honing these competencies, individuals can excel in their roles, drive advancements in additive manufacturing, and contribute to its continued growth and success. Ultimately, a comprehensive skill set in AM empowers professionals to overcome challenges, seize opportunities, and deliver high-quality outcomes in this dynamic and evolving industry.

Appendix 7: Skill Map

Appendix 8: Matching of Critical Skills to IAMQS Outcomes



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