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SAM: An opportunity to enhance AM educational programs through training centers and universities

1. The status of AM education in Europe

Additive Manufacturing (AM) is a promising technology that is expanding quickly in different sectors and domains. However, the wider adoption of AM is delayed by lack of suitability skilled workers. It is a fact that the development of the workers' qualifications drops behind the fast progress of AM technology evolution. To close this gap, therefore, European Commission has given special attention and investment to fund projects and initiatives focusing on developing skills and competences in the AM sectors. According to the result of mapping of projects in AM, conducted in the SAM project, a total of 48 projects were founded by 2019 (5 Erasmus+, 27 Horizon 2020, 16 others). This number corresponds to 29 on-going projects in the period 2019-2022 (14 Erasmus+, 12 Horizon 2020, 3 others). Moreover, according to the results of the AM-Motion mapping of AM educational initiatives, there were 41 courses and learning programs targeted different professional profiles on AM, conducted by universities and training centers across the Europe (AM-motion, 2018)

It is clear that education and research institutes across Europe will play an important role in shortening the existing knowledge and skills gap, through designing new educational programs. Fortunately, in recent years, advanced technological enhanced learning methods have enabled universities and educational institutes to offer specific courses, which address the needs and requests of the AM sector.

Two examples of AM courses for mechanical engineering students and the education of professionals are offered by Zurich University (Switzerland) and Afeka College (Israel).

Centre for Product and Process Development (ZPP) of the Zurich University of Applied Sciences ZHAW presents a training program for both students in mechanical engineering and in the counting education of professionals. This program consists of both theory and practice in the context of the Problem Based Learning method (PBL). Experimental learning and exploration in line with solving real problems achieves a balance between theory and practice in the accomplished learning outcomes. More importantly, the program brings not only a better understanding of the difference between AM technologies and conventional production process, but presents information from both an economic and ecological perspective (Kirchheim et al., 2017).

As another example, Afeka academic college of engineering proposed a novel AM course for mechanical engineering students. This course followed PBL method with the aim of teaching

AM technologies through handling challenges in real projects for manufacturing devices for disabilities. To measure the effectiveness of the course the performance of students was evaluated in every step of the course. The results showed a significant improvement both in technical (e.g. using AM-FDM technology, controlling the orientation of the printed objects, etc.) and soft skills (e.g. communication, team working, problem solving, etc.) (Stern et al., 2019).

2. SAM contribution and effort to elaborate AM education

2.1. Training survey

To gain a better understanding of the growing of number of specialized programs in AM education provided by universities, technical schools and vocational training centres, a survey to map educational practices among European institutes was conducted under the scope of the SAM project in 2020 The result of this survey is presented and discussed in the following section.

2.1.1. General information

A total of 96 universities and training centers across the Europe participated in this survey. The majority of participants were from Spain (23), France (17), Italy (16) and Portugal (13), respectively. Considering the mode of training, only 27.5% of institutes offered on-line training, however in the last 6 months, due to the Covid-19 crisis, more face-to-face training has been shifting to a virtual environment. Moreover, the result showed the most targeted sectors for AM courses were Industrial equipment and tooling (68%), Automotive (59%), and Aerospace (50%), respectively.

2.1.2 Professional profile

When questioned which AM professional profiles are currently relevant and will be needed in the future, Process engineer was indicated as the most demanding profession both at the present and in the next 5 years with 75% and 91% relevance respectively, followed by AM Designer and AM Material engineers. As shown in Figure 1, it is expected that all surveyed professional profiles in AM will get a higher relevance in the next 5 years.

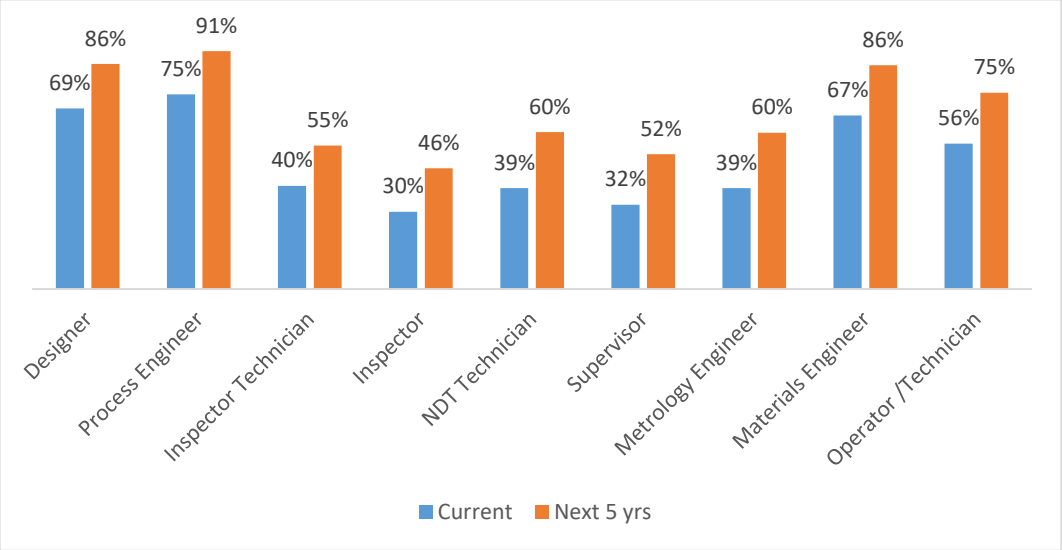

Figure 1: The relevance of Professional Profile at present and in the next 5 years

2.1.3. Taught skills

For Technological skills, the "AM process" was the most taught skill in AM courses as 91% of respondents mentioned its presence in the existing training courses, followed by "AM application" (85%). Regarding the missing AM skills in current available training courses, the SAM industry survey has indicated that only 18% of respondents stated that "Certification and Validation" was addressed in the AM courses, while for "Testing and Quality control" skills only 35% thought these skills were considered.

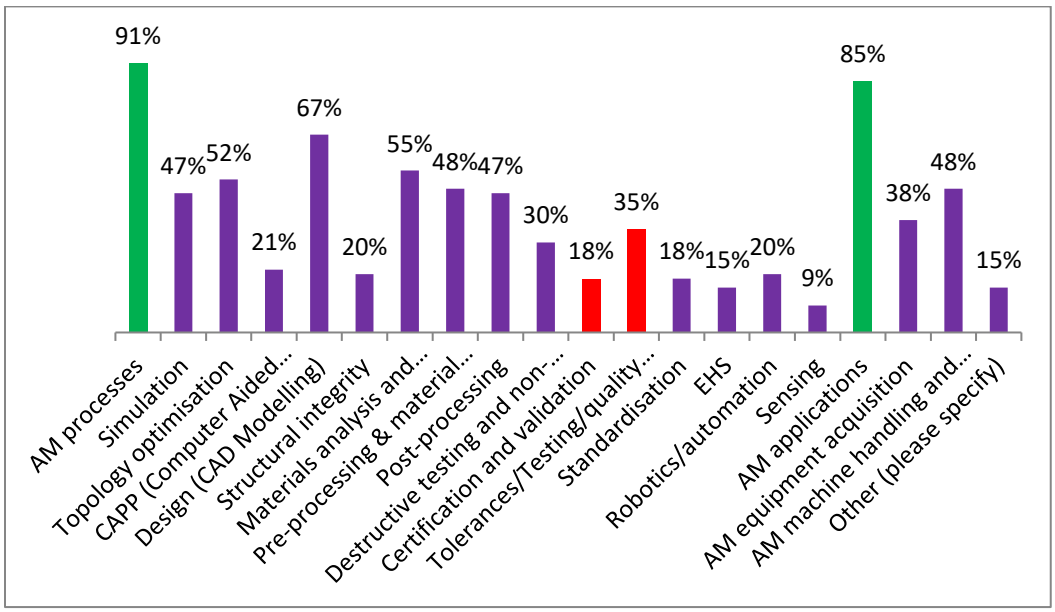

Figure 2: Distribution of Technological skills are being taught in AM courses

For Entrepreneurship skills, “Creativity” was the most taught skill in AM courses as 46% of respondents mentioned its presence in the existing training courses, followed by “Working with other” (42%),while the least one was “Mobilizing resources” (6%).

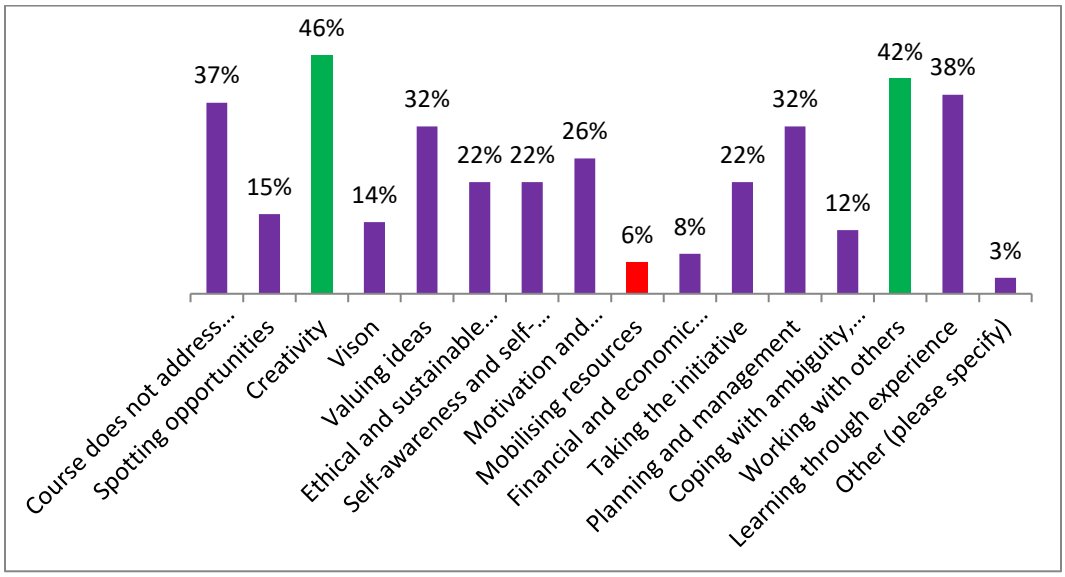

Figure 3: Distribution of Entrepreneurship skills are being taught in AM courses

For Digital skills, “Ability to think 3D” was the most taught skill in AM courses with 69% of respondents mentioned its presence in the existing training courses. The least one was considered was “Cybersecurity” (5%).

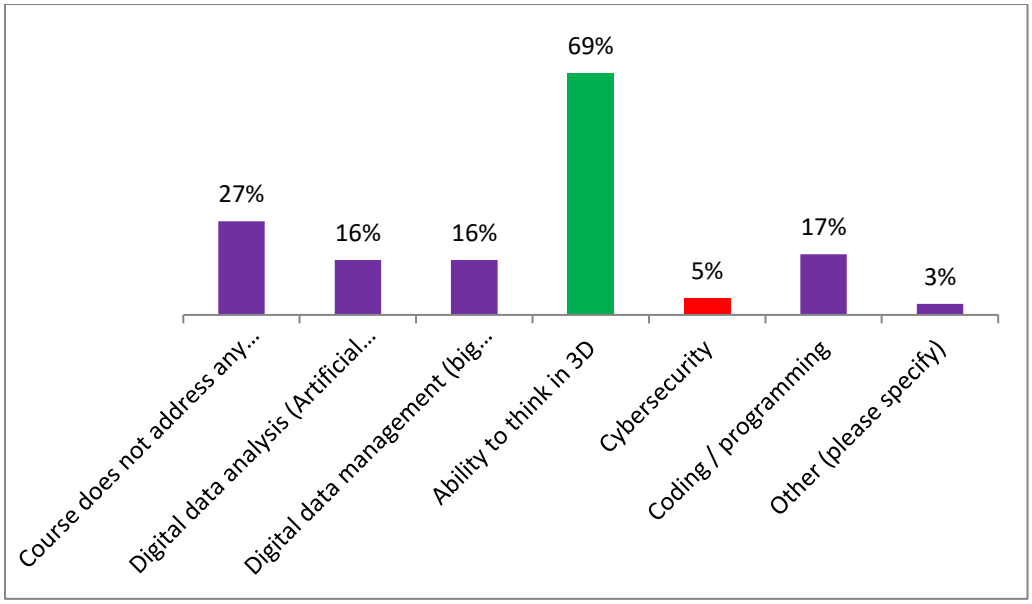

Figure 4: Distribution of Digital skills are being taught in AM courses

For Green skills, the most taught skill was “Eco-design” - 37% of respondents mentioned its presence in the training courses, followed by “Circular economy” (35%). The least skill considered here was “Green resources” (15%).

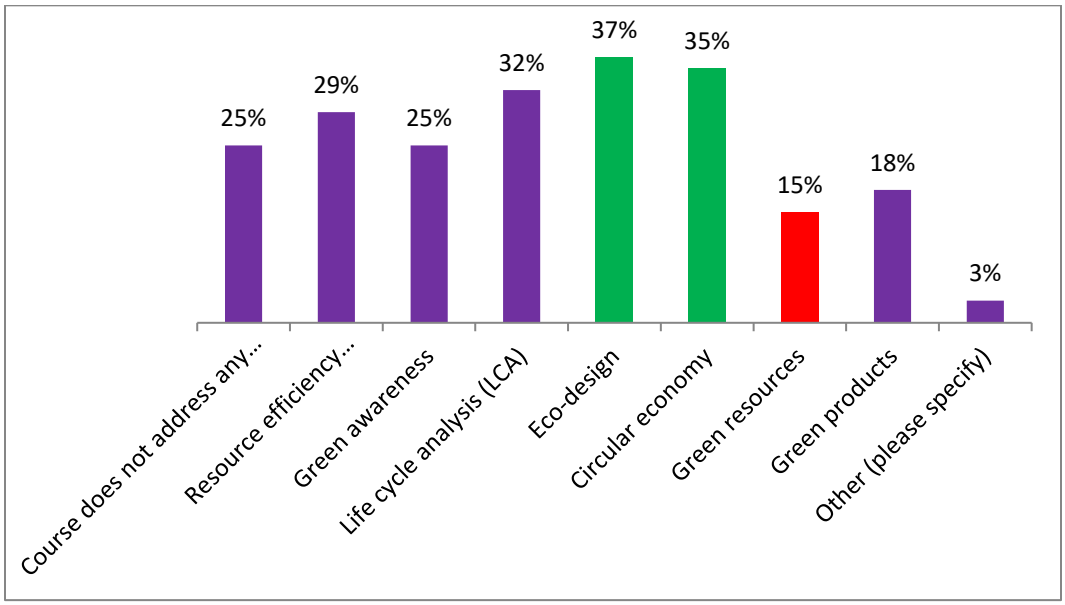

Figure 5: Distribution of Green skills are being taught in AM courses

2.1.4. Training tools

The SAM survey also measured the utilization of different training tools used in teaching AM skills in the training centers. The results have showed that “Lectures” generally was the most widely accepted tool in training the target skills (figure 6).

Namely it was the most popular tool for training Technological, Digital and Green skills with 89%, 67% and 80%, respectively. For the Entrepreneurship skill, it was the second acceptable tool (48%), where the most acceptable one was Case study (59%). Conversely, site visits were the least common of training tools, specifically for Digital and Green skills with 15% and 16%, respectively.

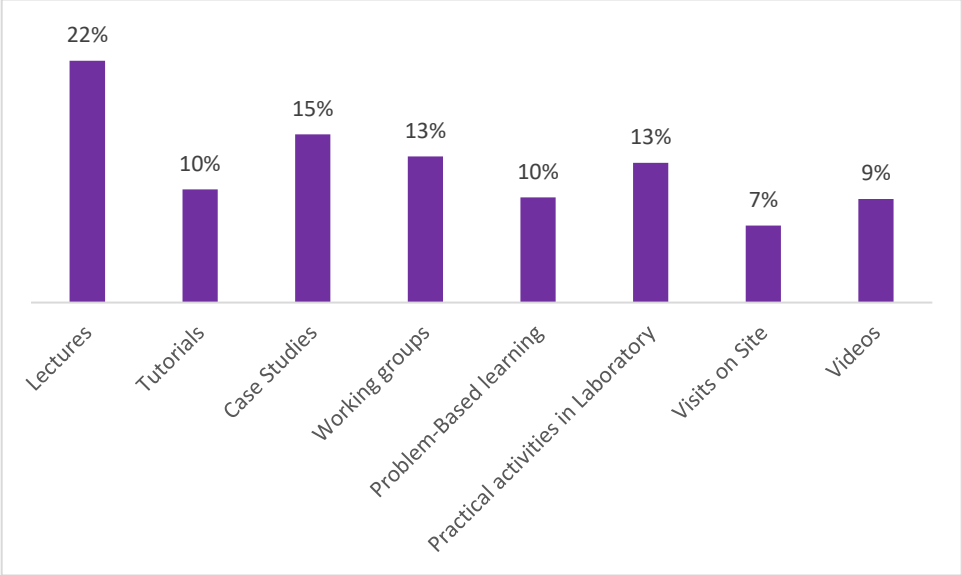

Figure 6: Distribution of usage different training tools in AM courses

2.2. SAM methodology to design professional profiles

A methodology to create and review professional profiles, qualifications, and units of learning outcomes has been developed under the scope of SAM project. Mapping the status of training contexts and training tools in AM education is one of the significant contributions of this methodology. The SAM report describes the currently in-use training contexts/tools consisting of "Advantages", "Constraints" and "Recommendations for AM training". Moreover, it includes examples of implementation of these training contexts/tools conducted by educational institutes from Germany, UK, and Spain.

3. AM education program in Ecole Centrale de Nantes

Ecole Centrale de Nantes delivers several lectures and courses to Engineering students and Master students.

Some of those lectures are fully dedicated to additive manufacturing challenges such as: the lecture on Additive Manufacturing and Advanced Manufacturing Processes for the "Advanced manufacturing" Master students, or the lecture on Rapid Manufacturing for 2nd and 3rd year Engineering students, or the lecture Fabrication Additive (in French) for Mechanical Engineering students, delivered by Prof. Hascoët. Other lectures are not fully dedicated to Additive Manufacturing but some specific aspects are addressed, like choice and use of materials, delivered by Dr. Rauch, or CAD/CAM delivered by Prof. Hascoët and Dr. Rauch, or Computer-aided decision-making processes to improve technological performance, delivered by Prof. Bernard. This last lecture includes some practical examples on how to take into account different KPIs (cost, quality and delay) to fix technological aspects (like for example position and orientation of parts, or support structures. A specific practical exercise for AM

costing is also presented to the students and illustrated on different case studies. Projects are also proposed to bachelor students, by Dr. Le Neel.
Most of the teaching activities are also demonstrated on technological platforms, 3D printing machines, shared in the Product and Systems Engineering Department, and an advanced rapid manufacturing platform, used also for research and in relation with companies, managed by Prof. Hascoët.

4. Conclusions

Education for Additive Manufacturing needs to be developed and emphasized in the different lectures and training courses in addition of more conventional practices and skills (Pei et al., 2019). To achieve these goals, the SAM project aims to develop a network of certified training centers through Europe and to encourage the Implementation of European Qualifications that are recognised by different sectors supported by a Quality Assurance System. The International AM Qualification System (IAMQS) has been developed based on industry requirements and engagement/consultations with industry experts to address the needs of different sectors. Currently, the IAMQS comprises covers Metal AM Qualifications for Operators, Designers, Supervisor, Inspector, Coordinator and Engineers. Furthermore, there are plans to create new Professional Profiles/Qualifications and Competence Units/ Training Modules, which will be implemented and recognised across different sectors.

Within the **Quality Assurance System underpinning the IAMQS, the** scope and curricula for AM are defined at European level through harmonised training guidelines and then taken up at the national level by the training centres, under supervision of the representative organisation in the AM field. The existence of the organisation supervising both AM training and assessment activities at the national level is of utmost importance to ensure harmonisation and quality in the delivery of AM Qualifications. Making it possible to leverage a single syllabus for each level of Qualifications, resulting in the same qualification being awarded in Europe, regardless of the What is important is that in ten years from now, Additive Manufacturing can become as well-known as conventional technologies with all the necessary training and qualifications in place. The main challenge to reach this goal, on one side, is related to technological platform; and on other side, it is associated with a strong dynamic process of technological transfer between research and innovation. Europe will have to face this challenge and requires to help certified centers to increase the number of qualified

experts, establish more comprehensive AM training and certifications and to extend their technological platforms with up-to-date technologies, representative of current and future practices.

5. References

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More information on SAM Project:

Keep yourself informed about progress and results on the project homepage: http://www.skills4am.eu

SECTOR SKILLS STRATEGY IN ADDITIVE MANUFACTURING

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