First expert workshop on "Aligning Advanced Manufacturing education and training with the 21st Century needs: Higher Education"

Curriculum Guidelines for Key Enabling Technologies (KETs) and Advanced Manufacturing Technologies (AMT)

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WORKSHOP REPORT

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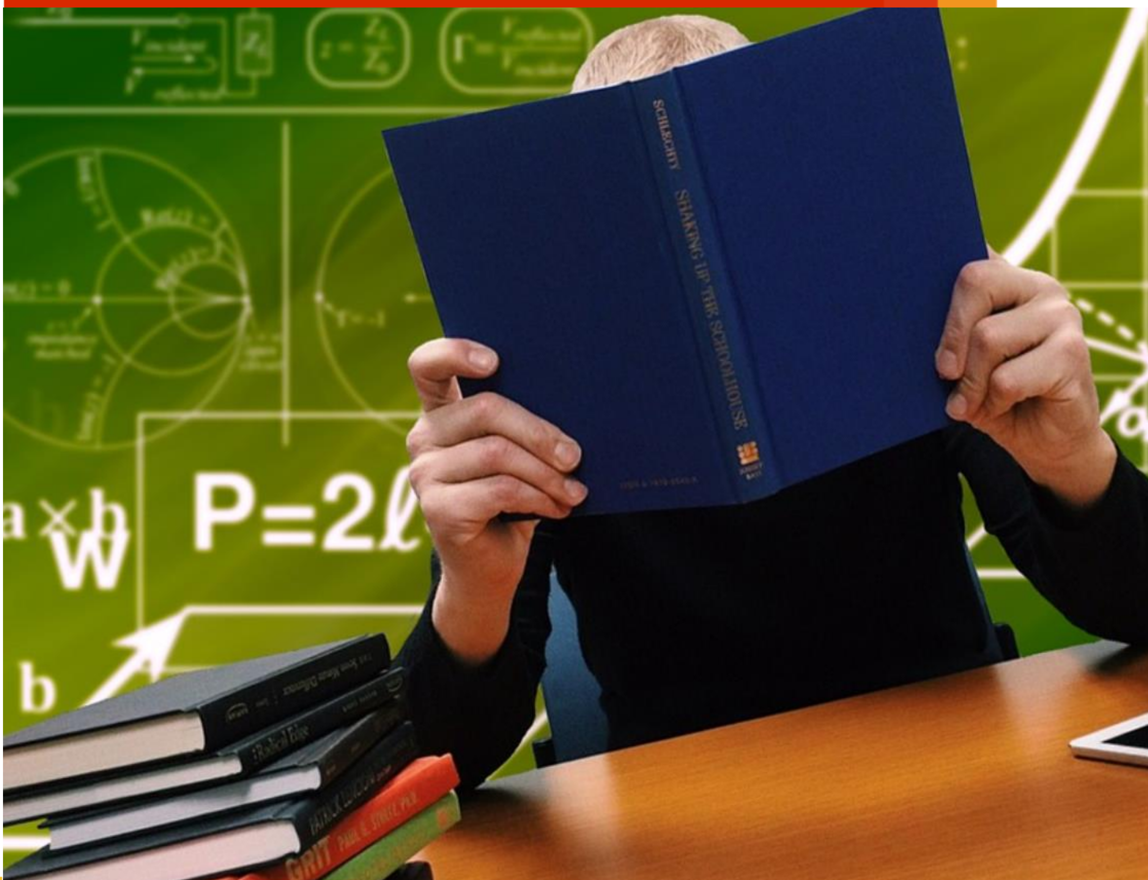

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Table of contents

Executive summary

This document summarises the key points discussed at the first expert workshop on "Aligning Advanced Manufacturing education and training with the 21st Century needs: Higher Education", organised in the context of the "Curriculum Guidelines for KETs and AMT" initiative of the European Commission.

The workshop aimed to focus on new/alternative approaches to Higher Education, and specifically Bachelor and Master Programmes, in the field of Advanced Manufacturing Technologies. During the workshop, the initial proposals for the design of the EU-wide curriculum guidelines were framed and discussed. The workshop aimed to feature good practice examples and practical illustrations of the proposed solutions.

The workshop brought together key practitioners, researchers and policy makers active in the field of AMT education & training in Europe. The outcome of the workshop will be used for shaping the curriculum guidelines for the EU Higher Education Institutions for years to come. The curriculum guidelines will be highlighting the key points of attention when it comes to aligning the approach towards AMT education & training with the 21^{st} Century needs. The guidelines will be developed based on the extensive state-of-play analysis and active stakeholder contribution.

The guidelines need to be applicable for both designing fundamentally new educational offers and/or advancing the existing curricula, depending on the level of required change. The objective is to offer educational and training institutions a source of inspiration, conceptual guidance and good practice examples.

The key outcomes of the discussion are as follows:

- There is still a strong misconception among students and broader public when it comes to the image of the manufacturing domain. The latter is associated with poor working conditions and lack of prestige.
- New technologies (such as 3d printing, robotics, etc.) can play a role in eliciting new interest in manufacturing among students and the broader public.
- There is a clear need to disseminate information on good practice examples among the educational institutions in Europe. It is crucial to explore the replicability of good practices, as awareness raising is meant to serve only as the first step towards replicating/upscaling successful practices.
- There is a need to look for financially sustainable business models for the educational offer such as, for example, sponsorship by companies that would like to have a tailor-made programme, alumni contributors, sublicensing etc.
- Online training solutions do not represent a replacement for traditional teaching. They are instead complementing it.
- A poor gender balance still remains an issue in the manufacturing domain.
- There is a need for change agents both within educational institutions and companies.
- Innovation in education needs to be rewarded in the academic career. So far, the focus of the reward system has mainly been on research and particularly publications. There is a need to extend the "excellence in science" principle towards "excellence in teaching".
- When it comes to relevant policy initiatives, they do not always have to be explicitly focussed on education & training to make an impact. Education & training elements can also be embedded into

broader programmes, as a compulsory element. In some existing (EU) initiatives, it has already been implemented.

1. Introduction

This document represents a workshop report for the first expert workshop on "Aligning Advanced Manufacturing education and training with the 21st Century needs: Higher Education". The workshop was organised in the context of the "Curriculum Guidelines for Key Enabling Technologies (KETs) and Advanced Manufacturing Technologies (AMT)" initiative (contract nr. EASME/COSME/2017/004), that is coordinated by PwC EU Services (PwC), under the auspices of the Executive Agency for Small and Medium-sized Enterprises (EASME) and the Directorate General for Internal Market, Industry, Entrepreneurship and SMEs (DG GROW) of the European Commission (the Commission). The workshop took place at Thon Hotel EU in Brussels (Belgium) on 12 June 2018.

The introduction session of the workshop included a brief presentation of the workshop context, rationale and objectives, as well as an introductory round of participants.

1.1. *Workshop context, rationale and objectives,* Kristina Dervojeda, PwC (Netherlands)

Dr. Kristina Dervojeda briefly addressed the context of the workshop, its rationale and objectives.

The manufacturing domain is undergoing a fundamental transformation (known as the fourth industrial revolution or Industry 4.0) that is driven by three major types of developments[1]:

- ***Technology trends***: the advancement of manufacturing is supported by a range of different emerging technologies and systems that enhance organisation, sharing and analysis of data; improved sensing and interacting with the material world; and greater connectivity, data gathering, and control of manufacturing system elements;

- ***Customer demand trends***: evolving customer preferences refer to product variety; personalised products and services; faster response to needs; expectations of added-value services (social media interaction, order status tracking); and societal and economic pressure to increase environmental and resource sustainability;

- ***Industry pressures and drivers***: there is an increasing need for asset and resource efficiency; growing reliance on supply chain and need for robustness and tracking; increasing security risks; shorter product lifecycles; emerging opportunities to offer value-added services throughout product life-cycle; and increasing manufacturing complexity of products, production and data.

These developments have **direct implications for the skills needs**. The AMT professionals need to possess skills related to digital technologies, analytical thinking, machine ergonomics, as well as understanding manufacturing technologies (including design for manufacturing, design for assembly and design for automation). The AMT domain also heavily relies on skills linked to merging and adaptation of technologies. Examples include merging laser technologies with printing techniques, rapid prototyping technologies with tissue scaffolding etc. Similar skills become increasingly needed also by lower levels in organisations, to be innovative about implementing process and technique changes. This also relates to management skills needed to recognise, understand and manage change[2].

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[1] UNIDO (2017) "Emerging Trends in Global Advanced Manufacturing: Challenges, Opportunities and Policy Responses", Report developed with support of the University of Cambridge and Policy Links, available at: https://institute.unido.org/wp-content/uploads/2017/06/emerging_trends_global_manufacturing.pdf
[2] *Ibid.*

The number of jobs in manufacturing as a whole requiring high-level qualifications is projected to rise by 1.6 million (21%) by 2025[3], whereas the growing automation of production processes will see the number of low- and medium-skilled jobs decrease by over 2.8 million. A similar pattern is expected in the high- and high-medium technology industries within manufacturing, although the shifts are less pronounced at the high-technology end of the scale[4].

The abovementioned challenges signify **a need to reconsider the current approach towards the education and training of AMT professionals** and to develop new/advanced models that would be better aligned with the needs of both employers and (future) employees.

To this end, EASME and DG GROW of the European Commission have recently launched a new initiative for developing **"Curriculum Guidelines for Key Enabling Technologies (KETs) and Advanced Manufacturing Technologies (AMT)"**. This initiative aims to contribute to increasing the quality and relevance of existing curricula and to promote better cooperation between industry and education and training organisations in order to align AMT education and training with the 21st Century needs. It involves data collection and research, design of guidelines, testing and validation, taking into account industry and market needs and best practices, based on contributions from key stakeholder groups. The initiative focusses on **VET, higher education and on-the-job training for AMT**.

Two distinctive but closely interrelated directions for action are being explored:

Teaching new skills:

- New technical skills, emotional/social intelligence, multidisciplinary mind-set, learning-to-learn skills, systems thinking, STEAM (STEM with Arts) etc.;

Teaching skills in a new way:

- Student-centric approach;
- Problem-based learning and experience-based learning (real-life cases, apprenticeships, engaging employers in curriculum development etc.);
- Technology-enhanced learning (MOOCs, augmented/virtual reality, AI etc.);
- Learning ecosystem: connecting learners to employers and other key stakeholders through project work, industrial placements, matchmaking events etc.
- Upskilling teachers and equipping them with the right tools.

The outcome of this initiative will play a prominent role in forming the EU policy making regarding upskilling of the AMT workforce.

The first expert workshop aimed to focus on **new/alternative approaches to Higher Education** (Bachelor and Master Programmes) in the field of Advanced Manufacturing Technologies. During the workshop, the initial proposals for the design of the EU-wide curriculum guidelines were framed and discussed. The workshop aimed to feature good practice examples and practical illustrations of the proposed solutions.

The workshop brought together key practitioners, researchers and policy makers active in the field of AMT education & training in Europe, with a particular focus on Higher Education. **The outcome of the workshop**

[3] European Commission (2014) "EU Skills Panorama: Focus on Advanced Manufacturing", available at: http://skillspanorama.cedefop.europa.eu/sites/default/files/EUSP_AH_AdvManufacturing_0.pdf
[4] *Ibid.*

will be used for shaping the curriculum guidelines for the EU Higher Education Institutions (HEIs) for years to come.

1.2. *Opening words,* André Richier, DG GROW, European Commission (Belgium)

Mr. André Richier welcomed all the participants and emphasised that the current initiative aims to:

- Promote better policies, measures and initiatives at all levels on KETs and AMT skills by fostering transparency and increasing awareness;
- Facilitate the uptake by SMEs of these technologies, by strengthening the human capital and skills dimensions and providing efficient tools (curriculum guidelines and quality labels);
- Improve the relevance and quality of curricula for KETs and AMT skills development;
- Contribute to the further development and improvement of European and national initiatives on KETs and AMT skills, including synergies with the activities within the Blueprint for Sectoral Cooperation on Skills (additive manufacturing) and EIT Knowledge and Innovation Communities (Added-value manufacturing KIC).

The overall goal of this initiative is to help the Commission assess the current state of play and identify the key focus areas for future efforts.

The initiative will involve data collection and research, design of guidelines, testing and validation, taking into account industry and market needs, best practices, and contributions from key stakeholder groups. **The aim is to help likeminded people to find/co-develop solutions and to provide guidance for implementation**.

The **target groups** of this initiative are, on the one hand, higher education students and teachers, and on the other, workers and managers (especially those employed by SMEs) who need to acquire continuously new specialised skills related to KETs, and specifically AMT. The outcomes of this initiative will contribute to the goals set out in the European KETs Strategy and the New Skills Agenda, and specifically the related sectoral pilots foreseen in the Blueprint for sectoral cooperation on skills.

This initiative also implies setting up an informal **Key Stakeholder Group** (KSG), i.e. a pool of highly qualified external experts that will be engaged in the current initiative by means of workshops, interviews, surveys etc. These people will form the base of the pan-European thematic network.

2. Advanced Manufacturing for the 21st Century: implications for skills and education

The morning session of the workshop was continued by the presentation on the actual 21st Century needs when it comes to skills and education. The objective of this presentation was to further set the scene for the workshop, collect initial expert feedback and frame the discussion.

2.1. *Recalling the 21st Century needs*, Kristina Dervojeda, PwC (Netherlands)

The "**Manufacturing professionals 4.0**" refer to all key groups of workers of the Advanced Manufacturing domain, that broadly speaking include technicians/operators, engineers and other highly skilled professionals (computer coders, app developers, data scientists, 3D printing specialists etc.) and managers.

According to the VDI White Paper (2015)[5], in order to derive skills and qualifications of the future manufacturing professionals, there is a need to consider three distinctive tiers:

- *Tier 3*: including factors that have a considerable influence on the workforce in a factory of the future, such as tools & technologies; organisation & structure; working environment, intraorganisational and interorganisational cooperation;
- *Tier 2*: Tasks;
- *Tier 1*: Skills and qualifications.

When it comes to **tools & technologies**, the factory of the future implies:

- a decreasing need to perform manual and routine tasks;
- access to real-time information on a certain situation to perform a task efficiently;
- worker's ability to control and monitor production processes through the analysis of data and information supported with devices;
- optimised human machine interfaces allowing the worker to make qualified decisions in a shorter time; *and*
- active use of collaborative robotics.

The observed change in the **organisational structure** refers to a decreasing need for workers to be bound to a certain production area, which leads to improved possibilities of job rotation and job enrichment. In addition, the factory of the future implies larger responsibility and more decision-making power; a mix of short- and long-term teams; and an ecosystem in which problem solving is done in collaboration with all participating parties on the shop floor and without much influence of a higher hierarchy. The latter signifies the transition towards a flat organisation structure.

The future **working environment** for AMT professionals is anticipated to represent an open, clean, and creative space. It is associated with improved ergonomics (due to automation of dangerous and hazardous jobs); active use of devices and assistance systems; and larger flexibility with respect to shifts or working day. The latter would lead to more transparent work planning, improved work-life balance, emergence of entirely

[5] VDI (2015) "A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective", April 2015, White Paper by the Association of German Engineers, with support of ASME American Society of Mechanical Engineers, available at: http://www.vdi.eu/fileadmin/vdi_de/redakteur/karriere_bilder/VDI-ASME__2015__White_Paper_final.pdf

new shift modes (no need to stand at one specific production station for the course of the entire shift), and opportunity to work from home.

The **intraorganisation and interorganisational cooperation** implies more teamwork, more cooperation, more communication. The factory of the future is associated with accelerated learning curves within production networks due to access to all kinds of information and data, and an opportunity to organise workshops, seminars, and training sessions within the cyberspace. Communication does not only happen with humans but also with other elements of cyber-physical systems, such as robots, machines, or the actual product. Service providers become increasingly able to access robotics systems in a manufacturing plant from outside the factory to perform service updates or react to errors right away. Increased collaboration can be observed with external parties and specifically research institutes, universities, and parties that are not classical suppliers, due to the interdisciplinary character of digital production.

The abovementioned developments signify changes in the associated **tasks** (Tier 2), and specifically lead to a greater task variety and the need for more qualified work. Monotonous and ergonomically challenging tasks are expected to decrease to a minimum due to automation. Tasks heavily based on data and information processing will be dominating, signifying a shift from material flow to information flow. Tasks will be mainly performed through devices and assistance systems.

The changes in tasks lead to changes in the **required qualifications and skills**. Key *technical skills* that are expected to be gaining importance include knowledge/data management skills; multi-disciplinary understanding of organisation, its processes and used technologies; IT security and data protection; proficiency in methodologies for real-time decision making (UNIDO, 2017); as well as computer programming or coding abilities or similar deep technical knowledge (useful but not compulsory). Key non-technical skills for the factory of the future include adaptability/flexibility, communication skills, teamwork skills, self-management, and a general mind-set for continuous improvement and lifelong learning.

When assessing the feasibility of developing such skills in the workforce, it is crucial to consider the key characteristics of the current and particularly upcoming workforce. **Millennials** are predicted to comprise 75 percent of the global workforce by 2025[6]. According to Sodexo 2017 Global Workplace Trends[7], this new generation generally seeks a bigger purpose in life, is highly educated, and represents natural innovators. They are particularly motivated by human contact, continuous feedback, training & development and flexibility. These all are highly relevant characteristics when it comes to meeting the abovementioned skills needs of the 21st Century.

The evolving skill requirements require **reconsidering the current approaches towards education and training** of AMT professionals. In general, there is a need for creating hands-on opportunities within education systems; close collaboration of business and educational institutions; offering students real-world experience, exposing them to real challenges and advancements of industry; focusing on real-world application of skills, and developing and elevating micro-credentialing programs for students and employees.

The current initiative aims to produce **guidelines** for education & training organisations, highlighting the key points of attention and good practice examples, when it comes to aligning their approach with the 21st Century needs. The guidelines will be developed based on the extensive state-of-play analysis and active stakeholder contribution. The aim is to follow a holistic approach covering a broad spectrum of dimensions relevant to curriculum design and implementation. Specifically, the following 8 dimensions will be considered by the **analytical framework**:

(1) Strategy;

[6] https://www2.deloitte.com/content/dam/Deloitte/global/Documents/About-Deloitte/gx-dttl-2014-millennial-survey-report.pdf
[7] https://www.sodexo.com/home/media/publications/studies-and-reports/2017-workplace-trends/unlocking-millennial-talent.html

(2) Collaboration;
(3) Content;
(4) Learning environment;
(5) Delivery mechanisms;
(6) Assessment;
(7) Recognition;
(8) Quality.

The essence of these dimensions will be addressed in more detail in the concluding session of the workshop.

The guidelines will be developed separately for VET, HE and on-the-job training.

2.2. *Discussion and feedback of participants*

Dr. Kristina Dervojeda invited the workshop participants to express their feedback regarding the presentations given during the morning session. The key points of the discussion included the following:

- The term "**operator**" needs to be used with caution as it primarily refers to the factory floor workers and does not include other relevant groups such as engineers (and other highly skilled professionals) and managers.

- **Millennials** in general do not seem to possess all the relevant characteristics to meet the 21st Century needs, and specifically **critical thinking** is often reported to be lacking. They are often referred to as "overeducated, but underskilled". Additionally, millennials tend to demonstrate a lack of loyalty to their employers.

- When talking about the skill requirements of the 21st Century, qualifications and skills related to **sustainability, circular economy and ethics** need to be taken on board, as they play a prominent role.

- There is a need for a **realistic view** of the situation in the manufacturing domain and for pragmatic approaches. It is important to understand how the resources need to be reallocated and what areas require the key attention.

- The **guidelines** that will be developed in the course of this initiative need to be applicable for both designing fundamentally new educational offers and/or advancing the existing curricula (depending on the level of required change). The objective is to offer educational and training institutions a source of inspiration, conceptual guidance and good practice examples.

- There is a need to portray the benefits and the value added of implementing the curriculum guidelines in order to generate a more responsive environment.

- The guidelines will focus on the education offer (programme/curriculum) rather than organisations as a whole.

3. *Teaching new skills and teaching skills in a new way (Part 1)*

The morning session included specific presentations featuring good practice examples with regard to teaching new skills and teaching skills in a new way. The session consisted of two presentations followed by a detailed discussion and feedback of participants.

3.1. *Successful examples of modern educational activities at Aalto University,* Esko Niemi, Aalto University (Finland)

Prof. Esko Niemi presented Aalto Junior Program, Aalto Design Factory and Aalto Ventures Program.

Aalto Junior program's mission is to support Aalto University's activities for schools, children, young people, parents and teachers. The aim of Junior is to promote the teaching and learning of natural sciences, mathematics, technology and arts at all levels and to support the children's and young people's hobbies.

Experiences from the program are positive and currently schools in the region are relocating themselves to Aalto University Campus. Aalto junior is part of national and indirectly Science on Stage Europe and EU STEM Coalition networks.

Aalto Design Factory (ADF) was born from a research project focused on creating an ideal physical and mental working environment for product developers and researchers. Today ADF is one of the spearhead projects and one of the first physical manifestations of Aalto University encouraging and enabling fruitful interaction between students, researchers, and professional practitioners.

Originating from product development and design education, Design Factory provides an environment that is suitable for experiential learning. The Design Factory approach combines disciplinary knowledge with design thinking and working life skills, such as collaborative working style, effective communication skills, and ability to implement theory to practice.

Elements of learning in ADF include having teacher as a facilitator and student as an active knowledge creator; information gathering and evaluation of various possible solutions; visualising, prototyping and experimenting with ideas; having a real-life problem as a basis for learning; interdisciplinary group work, and reflection.

The **Aalto Ventures Program** is an organisation within the Aalto University to promote entrepreneurial mindset and provide Aalto students with the inspiration, capability and network necessary to build new scalable businesses. The program provides MSc Startup minor and minors in Creativity and Venturing, Strategy and Corporate Renewal, Entrepreneurial Leadership; individual AVP courses to degree programs.

Seven educational principles of Aalto University include being learning-focused, promoting extended learning, learning through experience and reflection, enabling multi-disciplinarity, making it personal, holistic development and enabling critical thinking.

3.2. Lessons learned from changing education innovation culture at TU Delft, Tessa van Puijenbroek, TU Delft (Netherlands)

Ms. Tessa van Puijenbroek addressed the topic of how higher education is changing, based on TU Delft's experiences and approach.

Innovations in TU Delft's approach towards education include new types of learners and learning products, new digital learning activities, new ways of collaborating with (industry) partners, and new focus on education and educational developments.

Online education at the TU Delft is coordinated by the **Delft Extension School**[8]. The online education portfolio contains multiple Professional Educational Courses, over 50 free courses, and nearly 20 MSc and BSc courses. It is unique in volume and quality, ranging from free 8-week courses for all to specialised short courses for professionals. It is based on the model of the Harvard Extension School, in which the open and online education is offered to students from around the world[9].

New digital learning activities imply the use of virtual labs, VR/AR solutions, 3D simulation and gamification. **New ways of collaborating with (industry) partners** refer to a wide range of approaches including blended-learning-in-company, sublicensing, alumni-in-course-design, the use of business cases, co-creation with industry etc.

Universities of the future need to create room for Life Long Learning, reward education in the academic career and to scale up innovations with (EU) partners such as Virtual Exchange.

3.3. Discussion and feedback of participants

Dr. Kristina Dervojeda invited the workshop participants to express their feedback regarding the presentations given during the morning session. The key points of the discussion included the following:

- Many students do not find manufacturing jobs attractive. There is still a strong misconception when it comes to the **image of the manufacturing domain**.
    - It is a challenge to make sure that, for example, software developers move towards manufacturing and not ICT.
    - Promoting and raising awareness about the manufacturing domain in high schools, before students make the choice regarding their further education, helps to improve the reputation of the sector.
- There is a clear need to disseminate information on good practice examples among the educational institutions in Europe. It is crucial to explore the **replicability** of these good practices, as the specific objective is to replicate/upscale successful practices.
- There is a need to look for **financially sustainable business models** for the educational offer (e.g. sponsorship by companies that want a tailor-made programme; alumni contributors, sublicensing).
    - At this stage, public funding is still at a small scale. However, in the future, some key players might enter the market build "mega platforms".
- Students appreciate the practical applications that **gamification** brings in.

[8] https://www.tudelft.nl/technology-transfer/development-innovation/research-exhibition-projects/delft-extension-school/
[9] http://www.e-learn.nl/2014/01/23/tu-delft-starts-extension-school

- **MOOCs do not represent a replacement for traditional teaching**. They are rather complementing it.

4. Teaching new skills and teaching skills in a new way (Part 2)

The afternoon session continued with specific presentations featuring good practice examples with regard to teaching new skills and teaching skills in a new way. The session consisted of six presentations followed by a detailed discussion and feedback of participants.

4.1. *Additive Manufacturing: Overcoming workforce challenges to speed up its deployment in Europe,* Vincenzo Renda, CECIMO (Belgium)

Mr. Vincenzo Renda addressed the topic of workforce challenges in the field of Additive Manufacturing, and possible ways to tackle those challenges.

Recent CECIMO survey points to **continued demand for AM designers**. SMEs are at risk of lagging behind in competition to secure scarcely available specialised designers (they resort to in-house training).

AM industrialisation is also held back in Europe by **shortage of application engineers**. There is a lack of postgraduate (MsC) educational offerings in AM impacts on size of talent pool. There are just 6 postgraduate AM engineering programmes in Europe (4 of them are in the UK). Additionally, emphasis on soft skills is needed (problem solving and decision making skills).

There is also a **shortage of technicians**. A lack of competence transparency is reported, and employers struggle to properly assess the level of the candidate's expertise. There is a need for the EU-level system to create common standardised training.

Finally, there is **a need for the right managerial approach**. Potential end-users still think how to use AM as replacement of subtractive manufacturing. AM is complementary to current processes, it must be embedded into existing production lines to thrive. Management skills are needed to build confidence inside the company, formulate business models and create new companies out of it.

Approaching AM from an educational perspective is a challenging task. Metallurgical and digital aspects are interconnected making **profile interdisciplinarity** key. While AM developments happen at an increasingly fast pace, their integration into curricula happens slowly. Hands-on approach crucial to foster learning.

Recommendations for EU policy-makers include the need to explore opportunity to support multi-university AM postgraduate programme across Europe (at EQF level 7), emphasize training in EU-enabled demonstration facilities/DIH and facilitate access to AM training packages/AM hardware by European SMEs.

4.2. *The Role of Robotics in the future educational systems,* Jan Harder, Technical University of Munich (Germany)

Dr. Jan Harder addressed the role of robotics in the future educational systems.

The significance of robotics increased substantially over the last decade. First robonatives are growing up with real world robotics. However, there are some challenges associated with the perception of robots. Robots are often perceived as competitors instead of tools. There is also a highly exaggerated expectation induced by movies.

The major goals of **roboterfabriek** include offering holistic robotics education, creating robotic expertise in the general public, and raising acceptance of robotics in society. Roboterfabriek involves lectures, teacher training, Robothon University, Robothon Public School, Robothon Vocational School, Robotics workshops, as well as dissemination and networking activities.

Franka Emika Panda[10] is a robot arm that manipulates objects, accomplishing tasks it is programmed to do. It is a lightweight robot system designed to assist humans. It is available for under 10,000 EUR, making it affordable for small and medium-sized companies[11].

Robothon implies five days of activities starting from building a setup, developing an approach and time plan, then moving on to realisation and finishing with optimisation and presentation. Most of the funding for the design and implementation of the activities comes from the federal government.

4.3. *Developing world-class talent for manufacturing: Experience of the AMRC Training Centre,* Wendy Miller, the AMRC Training Centre, the University of Sheffield (United Kingdom)

Ms. Wendy Miller shared experiences of the AMRC Training Centre with regard to developing world-class talent for manufacturing.

The AMRC with Boeing, which has traditionally focused on high value low volume aerospace products, has 4 main areas of research: machining, assembly (the Integrated Manufacturing Group), composites manufacture and design, prototyping and structural testing. Partnering with the biggest names in the aerospace business, the AMRC focuses on the 3 Es; Engineering, Economical improvement and Environmental gains solving complex manufacturing problems.

Factory 2050 is the UKs first totally reconfigurable factory. Factory 2050 prepares the (future) workforce for the 4th Industrial revolution – the rise of the cyber-physical systems and introduces them to the next generation of manufacturing technologies. The four main research areas of the Integrated manufacturing group in Factory 2050 include Robotics and Automation, Integrated Large Volume Metrology, Digitally Assisted Assembly (DAA) and Manufacturing Informatics.

The AMRC Training Centre (AMRC – TC) was established in 2013 to build on the technical expertise of the Advanced Manufacturing Research Centre (AMRC). Its aim is to train the skilled engineers that manufacturing businesses need to compete in global high-value markets such as aerospace and power generation. Not only the larger employers but also the SMEs in the region. The Centre provides qualified employees with skills and hands-on experience of using state of the art machinery and technology. It has over 800 apprentices in training and some of them are now moving onto part time foundation degrees, full bachelor degrees and some have aspirations to do a PhD all accredited by The University of Sheffield.

The AMRC-TC is set up to replicate a work environment for apprentices. This includes a variety of apprenticeship pathways and continuous professional development (CPD) from mechanical manufacturing to electrical and mechanical maintenance, technical support and metals technologies, including welding and fabrication, ranging from Level 2 to Level 7.

The **core capabilities** of the AMRC group include:

[10] https://www.franka.de/panda
[11] http://www.dw.com/en/everyman-robot-panda-wins-german-presidents-future-prize/a-41591774

- Machining - applying the latest technology and innovative techniques, to develop, optimise and integrate machining solutions that deliver significant improvements in quality and cost;

- Integrated Manufacturing - bringing together advanced technologies and expertise spanning robotics and automation, virtual and augmented reality, digitally assisted assembly and large-volume metrology;

- Metrology - providing a range of dimensional metrology technologies and services to research groups and partners;

- Composite Manufacturing - developing machining, advanced curing and automated production techniques and exploring the potential of novel materials, processing technologies and hybrid parts combining high-performance metals and composites in a single structure;

- Design and Prototyping - providing customers with everything from concept designs and working drawings, to fully functional pre-production prototypes or research instrumentation;

- National Metals Technology Centre - addressing some of the fundamental, unresolved issues which are holding back the mass adoption of metal additive manufacturing processes;

- Structural testing - physically validating research, analysis, material properties, components, sub-assemblies, and full assemblies for both research and commercial projects.

- Castings - developing new casting technologies and techniques and providing advanced casting expertise.

The high cost of fees has an effect on choices for those whose parents are not in a position to fund their young person. However, the **employer** funds payment for the degree programmes. Many of the Training Centre apprentices did not have aspirations at pre-16 to gain a HE qualification and would never have considered going to university, but due to the blended learning of academic and vocational education and success in their studies have decided for the option.

Key benefits of the AMRC educational/training offer include the following:

- No student loan;
- Students already in employment;
- Taught by practising engineers from a variety of backgrounds;
- Based at the AMRC;
- Content developed with employer input;
- Academic learning will complement and enhance existing vocational experience;
- Maturity of students and self-direction;
- Strong link between taught material and practical application;
- Variety of teaching methods interspersed with labs and field trips;
- Utilisation of latest learning technology;
- Small group tuition.

Both politicians and economists have recognised that the collaboration between business and universities creates economic growth. Through the setting up of the AMRC the Sheffield University also recognised a gap in the skills to provide high-value manufacture and research. The overall goal is to bring investment to the region – develop the human capital to do so.

4.4. *Teaching new technologies at BSc and MSc levels: Bringing together design and manufacturing*, Manuel Freitas, MIT Portugal (Portugal)

Prof. Manuel Freitas addressed an issue of teaching new technologies at BSc and MSc levels based on the example of MITPortugal Program.

MITPortugal Program is an educational & research program, financed by FCT - Portuguese Foundation for Science and Technology, between MIT – Massachussets Institute of Technology and Portuguese universities. Its key focus areas include Sustainable Energy Systems, Transportation Systems, Bioengineering Systems and Engineering Design and Advanced Manufacturing.

The mission of **Engineering Design and Advanced Manufacturing (EDAM)** is to develop **a new educational engineering paradigm**, with high quality research closely linked to novel curricular programs, to promote a new entrepreneurial attitude towards knowledge-based manufacturing and competitive product development. The key principles it relies on include solid scientific background, creativity, innovation, environmental and economical concern and leadership.

The mission of the **Design Studio & Product Development Laboratory** is to promote engineering design competencies through collaborative research and education programmes; to expand the awareness of engineering design through education, the development of new teaching curricula and materials for use in engineering and business education; and to establish public-private partnerships and industry-science relationships aimed to improve industrial competitiveness.

The objectives of **Process-Based Cost Model (PBCM)** are to determine the economic performance of innovative product design, introduction of new materials and introduction of new technologies, through Process Based Cost models, and by providing comparison between technologies using standard production parts.

MITPortugal, EDAM focus area was found to be a fruitful program between Engineering Systems Division from MIT and Mechanical and Materials Departments of Portuguese universities. Product Development courses and laboratories were found to be an excellent educational path to teach engineering design at BSc and MSc levels. In Engineering Design and Product Development, subjects like **creativity, innovative materials, new technologies and cost models** must be present in order to evaluate the feasibilty of the product.

4.5. *Designing with factories of the future: online and offline learning for creative industry*, Jouke Verlinden, University of Antwerp (Belgium)

Prof. Jouke Verlinden addressed a topic of design with factories of the future, and specifically the aspects of online and offline learning for creative industry.

The concept of **Human-Centred Digital Fabrication** implies the interaction of three elements, namely Human user, designer, worker), Production Process (3D printing, robotics, CNC, 3d scanning) and Product (hierarchical materials, special features, aestetics, ergonomics).

Advanced Manufacturing makes the design leaner by offering opportunities for:

- modeling products & processes, 3D scanning and reverse engineering;
- hands-on making: prototyping, videos & photography, weblogs, wikis;
- design for Additive Manufacturing, (topological) optimisation, digital materials (CAD++);
- iterative development processes, decision making, stakeholder analysis, documentation & communication;
- entrepreneurship, crowdfunding, presentation.

A dedicated online course was developed on "**Digital Manufacturing for Industrial Design**" and offered through the edX platform in 2017 and 2018. The course implies learning about the design process and different techniques of digital manufacturing. The learners are offered an opportunity to put it into practice through hands-on assigments using software. The course implies 20 study hours in total, in 4 weeks. It involves video lectures (5), professional interviews (5), and a webinar. Furthermore, it includes weekly assignments, forum discussions, and a video wrap-up.

The first results of the online course were beyond expectations. Active facilitation proves to lead active participation. An offline approach proves to be more suitable for more comprehensive aspects (hands-on, exhibits, installed software). It can be effectively supported by video lectures & assignments.

4.6. *Teaching Factory*, Konstantinos Georgoulias, University of Patras (Greece)

Dr. Konstantinos Georgoulias presented a concept of a Teaching Factory, **aiming to integrate the real factory environment with the classroom**. The Teaching Factory paradigm uses advanced ICTs and high-grade industrial didactic equipment to operate as a non-geographically anchored learning "space".

Skills have a major impact on the economic growth of society, on the innovation process as well as on industry's competitiveness. The Teaching Factory demonstrates high-degree of modularity and can therefore be adapted to the needs of both academia and industry. Multiple, remotely located "factories" and "classrooms" are envisioned. New technologies and manufacturing concepts can be exchanged. The use of the Teaching Factory concept can encourage entrepreneurship in universities and innovation within companies, through shared projects between academia and industry. Finally, the Teaching Factory can also be used to train suppliers/subcontractors of OEMs, in cooperation with academia.

4.7. Discussion and feedback of participants

Dr. Kristina Dervojeda invited the workshop participants to express their feedback regarding the presentations given during the afternoon session. The key points of the discussion included the following:

- A poor **gender balance** still remains an issue in the manufacturing domain.
- There is a need for **change agents** both within educational institutions and companies.
- **Innovation in education needs to be rewarded** in the academic career. So far, the focus of the reward system has mainly been on research and publications. There is a need to extend the "excellence in science" principle towards "excellence in teaching".
- When it comes to relevant policy initiatives, they do not always have to be explicitly focussed on education & training to make an impact. **Education & training elements can also be embedded** into broader programmes, as a compulsory element. In some existing (EU) initiatives, it has already been implemented.
- There is a need to take action on **educating people about working with robots**. Once they start using robots, the "fear of technology" disappears.

5. Moving forward: conclusions and next steps

The closing session of the workshop aimed to address the detailed proposals for curriculum guidelines, summarise the key points of discussion and identify the next steps.

5.1. Towards detailed proposals for curriculum guidelines

The analytical framework that will be forming a base for collecting and framing relevant data and developing guidelines, consists of 8 distinctive, but interrelated dimensions:

(1) Strategy;
(2) Collaboration;
(3) Content;
(4) Learning environment;
(5) Delivery mechanisms;
(6) Assessment;
(7) Recognition;
(8) Quality.

Strategy (1) refers to defining core values, commitments, opportunities, resources and capabilities of an educational/training institution with respect to developing a 21st century curriculum for AMT. The focus will be put on the conceptual aspects of the educational offer. Specifically, the elements of strategy include assessing learner's needs, developing curriculum goals and intended learning outcomes.

Collaboration (2) refers to connecting individuals and institutions by facilitating the exchange of practices and resources with a view to improve the educational offer. Special attention will be paid to practices that move beyond the typical institutional collaboration patterns and engaging individuals and communities. We also aim to address practices that empower learners to collaborate with each other and with the institution and community in order to produce knowledge, define their unique learning paths and achieve their goals.

The nature of educational **content (3)** includes multiple factors, such as degree of familiarity (from very familiar to novel), degree of learner engagement (from intellectual activity to behavioural activity), degree of anticipated change (from making learners aware of information to influencing their personal values), and degree of complexity (from easily understandable to very complicated). This dimension also includes specific principles related to the actual content of the curricula (syllabus design principles).

Learning environment (4) includes types of environment that is created during the program, e.g. stimulating multidisciplinary orientation, design thinking, team spirit, collective problem-solving, risk-taking behaviour, experimental approaches etc.

Delivery mechanisms (5) refer to the means by which learners experience and access education/training, and include in-person delivery where teachers/trainers and learners interact face-to-face (e.g. lectures, seminars, workshops); electronic delivery (synchronous and asynchronous), and blended delivery (education that combines multiple types of delivery). Here, we aim at addressing the role of technology-enabled learning, including traditional e-learning, MOOCS, SPOCs, mLearning, gaming, virtual and augmented reality, AI solutions etc.

We also aim at exploring the most appropriate forms of **assessment (6)**, e.g. self-assessment through which students learn to monitor and evaluate their own learning (trains the ability to be reflective and self-critical).

peer assessment, in which students provide feedback on each other's learning, tutor/institutional assessment, in which the assessment is performed based on the judgement of tutor or standardised assessment test, other alternative forms of assessment.

Recognition (7) refers to the process, usually carried out by an accredited institution, of issuing a certificate, diploma or title which has formal value; and the process of formally acknowledging and accepting credentials, such as a badge, a certificate, a diploma or title issued by a third-party institution. Within this dimension, we aim at exploring appropriate formal and informal ways of recognition.

Finally, we aim to explore the **quality (8)** dimensions of an educational offer, by looking at:

- efficacy (fitness for purpose of the object/concept being assessed),
- impact (the extent to which an educational offer proves effective),
- availability (this is a pre-condition for efficacy and impact to be achieved, it includes concepts such as transparency and ease-of-access),
- accuracy (is a measure of precision and absence of errors, of a particular process or object), and
- excellence (compares the quality of an object or concept to its peers, and to its quality-potential).

5.2. Next steps

The project team will keep the workshop participants informed about the key activities of the initiative, and further involve them in co-creating specific proposals for curriculum guidelines.

The workshop participants expressed their willingness to continue following the progress of the initiative and to provide additional suggestions and feedback, whenever needed.

Annex A: Workshop agenda

Workshop agenda

10:00 – 10:30	**Welcome and Introduction** • Workshop context, rationale and objectives • Introduction round of participants • Workshop setting and key expectations	*André Richier (DG GROW, European Commission)* *Kristina Dervojeda (PwC)*
10:30 - 11:00	**Advanced Manufacturing for the 21st Century: implications for skills and education** • Key findings from the PwC survey of manufacturers on talent • Key findings from the initial state-of-play analysis	*Kristina Dervojeda (PwC)*
11:00 - 12:00	**Teaching new skills and teaching skills in a new way (Part 1)** • **Successful examples of modern educational activities at Aalto University**, *Esko Niemi*, Aalto University (Finland) • **Lessons learned from changing education innovation culture at TU Delft**, *Tessa van Puijenbroek,* TU Delft (Netherlands)	*Moderators: Kristina Dervojeda (PwC), Erisa Gruda (PwC)*
12:00 - 12:30	**Discussion and feedback of participants**	*Moderators: Kristina Dervojeda (PwC), Erisa Gruda (PwC)*
12:30 – 13:00	**LUNCH BREAK**	
13:00 - 15:00	**Teaching new skills and teaching skills in a new way (Part 2)** • **Additive Manufacturing: Overcoming workforce challenges to speed up its deployment in Europe**, *Vincenzo Renda*, CECIMO (Belgium) • **The Role of Robotics in the future educational systems**, *Jan Harder*, Technical University of Munich (Germany) • **Designing with factories of the future: online and offline learning for creative industry**, *Jouke Verlinden*, University of Antwerp (Belgium) • **Teaching new technologies at BSc and MSc levels: Bringing together design and manufacturing**, *Manuel Freitas*, MIT Portugal (Portugal)	*Moderators: Kristina Dervojeda (PwC), Erisa Gruda (PwC)*

	• **Developing world-class talent for manufacturing: Experience of the AMRC Training Centre**, *Wendy Miller,* the AMRC Training Centre, the University of Sheffield (United Kingdom) • **Teaching Factory**, *Konstantinos Georgoulias*, University of Patras (Greece*)*	
15:30 - 16:00	**Wrapping up: Towards detailed proposals for curriculum guidelines** • Moving forward: conclusions and next steps • Closing remarks	*André Richier (DG GROW, European Commission), Kristina Dervojeda (PwC)*

Annex B: Workshop participants

Nr	Name	Organisation	Country
1.	*Esko Niemi*	Aalto University	Finland
2.	*Tessa van Puijenbroek*	TU Delft	Netherlands
3.	*Vincenzo Renda*	CECIMO	Belgium
4.	*Jan Harder*	Technical University of Munich	Germany
5.	*Jouke Verlinden*	TU Delft	Netherlands
6.	*Manuel Freitas*	MIT Portugal	Portugal
7.	*Wendy Miller*	AMRC Training Centre, the University of Sheffield	United Kingdom
8.	*Chris Decubber*	EFFRA	Belgium
9.	*Wieteke de Kogel*	Manufacturing Systems, University of Twente	Netherlands
10.	*Bogdan Dybała*	CAMT - Centre for Advanced Manufacturing Technologies	Poland
11.	*Carina Girvan*	Cardiff University	United Kingdom
12.	*Daniel Brissaud*	Grenoble Institute of Technology, KIC Added Value Manufacturing	France
13.	*Cecilia Berlin*	Chalmers University of Technology	Sweden
14.	*Annelies Raes*	KU Leuven	Belgium
15.	*Valerie Rocchi*	Grenoble Institute of Technology	France
16.	*Konstantinos Georgoulias*	University of Patras	Greece
17.	*Giovanna Daddamio*	EASME	Belgium
18.	*André Richier*	European Commission, DG GROW	Belgium
19.	*Ana Grigore*	European Commission, DG RTD	Belgium
20.	*Szabolcs Szekacs*	European Commission, DG GROW	Belgium
21.	*Kristina Dervojeda*	PwC	Netherlands
22.	*Erisa Gruda*	PwC	Netherlands