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Expert workshop on "Reshaping Higher Education for Advanced Manufacturing: 21st Century Strategy, Collaboration Patterns and Learning Environment"

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

WORKSHOP REPORT

Fourth expert workshop
Contract nr EASME/COSME/2017/004

EUROPEAN COMMISSION, Executive Agency for Small and Medium-sized Enterprises (EASME), Department A – COSME, H2020 SME and EMFF, Unit A1 - COSME

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Executive summary

This document summarises the key points discussed at the fourth expert workshop focussing on "Reshaping Higher Education for Advanced Manufacturing: 21st Century Strategy, Collaboration Patterns and Learning Environment", organised in the context of the "Curriculum Guidelines for KETs and AMT" initiative of the European Commission.

The results of our pan-European online survey indicated that the three elements of the AMT-related education & training system that require the most substantial change include Strategy (e.g. strategies for assessing learner's needs, developing curriculum goals and intended learning outcomes); Collaboration (e.g. engaging companies throughout the whole curriculum development & implementation trajectory, empowering learners to collaborate with each other and with the institution and community etc.); and Learning environment (e.g. stimulating multidisciplinary orientation, design thinking, team spirit, collective problem-solving, risk-taking behaviour, experimental approaches etc.). The workshop aimed to specifically focus on these three elements in the context of Higher Education for Advanced Manufacturing. The workshop featured good practice examples and suggestions for specific measures and solutions for EU/national policy makers, education providers and other key stakeholder groups.

The outcome of the workshop will be used for shaping the curriculum guidelines for the EU education & training providers active in the AMT domain 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 21st 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 need for educational leadership. Without top-down coordination and vision, there will hardly be a systematic change.

- To succeed, universities need commitment from both higher and lower levels of the organisation. Professors should be committed to the defined learning outcomes and deliver quality in teaching, while a committed programme head is responsible for the "complete picture".

- Highly complex problems and solutions require interdisciplinary knowledge and competences. The curriculum will need to be reorganised around new student-centred and blended learning models, with problem-based projects across disciplines and together with stakeholders. Problem-based learning has to be a coordinated approach across disciplines in shared projects, where students will have to apply a variety of skills to solve a problem.

- Student-centred learning is not a one size fits all approach. In order to succeed, it is essential to make sure students are considered equal partners in their own learning. It requires investments in active student-teacher communication and training of teachers.

- Collaboration with industry and companies is essential to enhance learning outcomes, and to better align Higher Education for Advanced Manufacturing with industry needs. Collaboration can occur at several levels: company as informant, company as case, company as client and company as project partner.

- The need for advanced manufacturing skills is influenced by a large spectrum of drivers, including technological development, environmental change and changes is societal expectations. The transformation of learning and teaching in Higher Education is not happening in isolation. Higher Education should be considered as part of an educational chain or ecosystem.

- There is a need for a holistic approach with (improved) instruments to enhance Higher Education in Advanced Manufacturing and to improve the competitiveness of European industry.

1. Introduction

This document represents a workshop report for the expert workshop on "Reshaping Higher Education for Advanced Manufacturing: 21st Century Strategy, Collaboration Patterns and Learning Environment". 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 5 March 2019. It is the fourth out of the six workshops that are foreseen in the context of the abovementioned initiative.

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

Mr. André Richier welcomed all the participants and emphasised that the current initiative aims to help the Commission assess the current state of play and identify the key focus areas for future efforts when it comes to aligning AMT-related education and training with the 21st Century needs. Another important goal is to identify key stakeholders and experts and bring them together in order to jointly identify key challenges, develop a shared vision and solutions and share, enhance, promote and scale-up best practices.

In parallel to this initiative, the European Commission is coordinating a Blueprint for Sectoral Cooperation on Skills for Additive Manufacturing. The Blueprint is a framework for strategic cooperation in the domain of Additive Manufacturing to address short and medium-term skills needs.

This initiative on "Curriculum Guidelines for KETs and AMT" is preparing the Commission to take further action by identifying needs, expectations and best practices. Following the final conference of this initiative on November 12th 2019, the implementation of recommendations and further actions to enhance, promote and scale up best practices within AMT education and training will continue in joint effort with a broad community of stakeholders.

1.2. *Workshop context, rationale and objectives,* Marte Andresen, PwC (Netherlands)

Ms. Marte Andresen 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 the following major developments[1]:

- **Technology trends;**
- **Customer demand trends;**
- **Industry pressures and drivers**;

[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

- **Policy and regulatory developments.**

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. The AMT domain also heavily relies on skills linked to merging and adaptation of technologies. 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].

An extensive analysis of skill requirements for KETs professionals has been performed by PwC in the context of the "Vision and Sectoral Pilot on Skills for Key Enabling Technologies" initiative (2014 – 2016) (hereafter "KETs Skills Initiative") for DG GROW of the European Commission[3]. KETs professionals here refer to all key groups of workers active in KETs domains, that broadly speaking comprise operators, technicians, engineers and managers. When the KETs Skills Initiative was carried out, KETs included Micro-/Nanoelectronics, Nanotechnology, Photonics, Advanced Materials, Industrial Biotechnology and Advanced Manufacturing Technologies[4].

The following six categories of KETs competencies were identified[5]:

(1) **Technical**: competencies related to practical subjects based on scientific principles (e.g. programming, computational thinking, mathematical modelling and simulation, top-down fabrication techniques etc.);
(2) **Quality, risk & safety**: competencies related to quality, risk & safety aspects (e.g. quality management, computer-aided quality assurance, quality control analysis, emergency management and response, industrial hygiene, risk assessment etc.);
(3) **Management & entrepreneurship**: competencies related to management, administration, IP and finance (e.g. strategic analysis, marketing, project management, R&D management, IP management);
(4) **Communication**: competencies related to interpersonal communication (e.g. verbal communication, written communication, presentation skills, public communication, virtual collaboration);
(5) **Innovation**: competencies related to design and creation of new things (e.g. integration skills, complex problem solving, creativity, systems thinking); and
(6) **Emotional intelligence**: the ability to operate with own and other people's emotions, and to use emotional information to guide thinking and behaviour (e.g. leadership, cooperation, multi-cultural orientation, stress-tolerance, self-control).

KETs rely on a balance of **both technical and non-technical competencies**.

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**

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[2] 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

[3] PwC (2016) "Final report on Vision and Sectoral Pilot on Skills for Key Enabling Technologies", prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

[4] In line with the initial definition of the Commission's Staff Working Document "Current situation of Key Enabling Technologies in Europe" SEC(2009) 1257. In the meantime, the definition of KETs by the European Commission has been adjusted. KETs currently include Materials and Nanotechnology, Photonics and Micro- and Nano-electronics, Life Sciences Technologies, Artificial Intelligence, Digital Security and Connectivity (based on the report from the High-Level Strategy Group on Industrial Technologies (2018) "Re-finding industry", Conference document, 23 February 2018).

[5] PwC (2016) "Final report on Vision and Sectoral Pilot on Skills for Key Enabling Technologies", prepared for DG GROW of the European Commission, Service contract nr. SI2.ACPROCE060233200

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 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 initiative focusses on **VET, higher education and on-the-job training for AMT**. The objective is to offer educational and training institutions a source of inspiration, conceptual guidance and good practice examples.

Two distinctive but closely interrelated directions for action are being explored, namely teaching new skills and teaching skills in a new way.

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

The tasks of this initiative are grouped into three Work Packages (WPs) corresponding to the two main phases of 12 months each.

The **first phase** was dedicated to research, collection and analysis of latest information and data, based on desk research, expert workshops and interviews with key stakeholders. An interim report, presenting the results of the analysis and the state-of-play in the EU on education & training for AMT, signifies the end of this phase. The interim report will later be integrated into the final report.

The **second phase** will concentrate on documenting best practices, engaging a broader ecosystem of stakeholders, designing European curriculum guidelines and quality labels for AMT, and formulating recommendations. A final report will be delivered at the end of this phase.

The **Interim Report** for this initiative has been published online[6]. The Interim Report contains preliminary findings and conclusions elaborated during the first phase (January-November 2018) and is made public for stakeholder consultation, and specifically for collecting feedback and additional inputs that can be used in the second phase. The workshop participants were invited to provide their feedback on the report.

In total, six expert workshops are foreseen in the context of this initiative, where the current workshop is the fourth.

The first expert workshop, held in Brussels on 12 June 2018, aimed to focus on **new/alternative approaches to Higher Education, and specifically Bachelor and Master Programmes, in the field of AMT**. It was concluded that there is a clear need to disseminate information on good practice examples among the educational institutions and companies 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 also 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. 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.

The second expert workshop, held in Brussels on 18 September 2018, focussed on the initiatives aiming **to improve curricula/learning strategies for on-the-job training in the field of AMT**. The workshop suggested that there is a need for a dedicated learning platform that would comprehensively combine a wide range of relevant courses with dedicated learning modules and link them to specific learning paths. Policy

[6] The report is available on EU Publications at: https://publications.europa.eu/en/publication-detail/-/publication/4dcaeee3-29c2-11e9-8d04-01aa75ed71a1/language-en/format-PDF/source-87225354

makers could play a role in facilitating the process of creating and maintaining such a platform. Special attention needs to be paid to new/updated job descriptions. Motivation of the learner is one of the key factors for successful upskilling/reskilling. It is suggested to play a more important role than education.

The third expert workshop, held in Brussels on 13 December 2018, focused on the initiatives aiming **to improve curricula/learning strategies for non-tertiary vocational education in the field of AMT**. The workshop featured good practice examples and practical illustrations of the proposed solutions from Vocational Education and Training (VET) providers. During the workshop, it was emphasised that the role of schools, teachers and trainers needs to be reconsidered, with the learning ecosystem built around learners. The role of the schools is to teach the basics that can be further built on by applying, for example, a "nugget approach". There is also a high risk of developing unrealistic expectations regarding what students should know when they finish their studies. Since it is not possible to address every need, finding a good balance is key.

The results of our pan-European online survey (conducted in the end of 2018) indicated that **the three elements of the AMT-related education & training system that require the most substantial change include**:

- **Strategy**: What are promising strategies and conceptual principles for developing a 21st Century curriculum for Advanced Manufacturing? (including strategies for assessing learner's needs, developing curriculum goals and intended learning outcomes)

- **Collaboration**: What are promising collaboration practices for facilitating the exchange of knowledge and resources with a view to improve the educational offer for Advanced Manufacturing? (e.g. engaging companies throughout the whole curriculum development & implementation trajectory, empowering learners to collaborate with each other and with the institution and community etc.)

- **Learning environment**: What types of environment lead to the most effective learning for Advanced Manufacturing? (e.g. stimulating multidisciplinary orientation, design thinking, team spirit, collective problem-solving, risk-taking behaviour, experimental approaches etc.)

To this end, the current workshop aimed to specifically focus on these three elements. These elements were further explored in the context of **Higher Education for Advanced Manufacturing**. The workshop particularly aimed to offer a discussion platform to address key challenges and actions that would need to be introduced at the EU level. This 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 elaborating the curriculum guidelines for education & training providers** active in the AMT domain.

2. Reshaping Higher Education for Advanced Manufacturing: Mission Impossible?

The morning session of the workshop was continued by the presentation on the results of the online survey (end of 2018), an update on the Curriculum Guidelines Framework, and the key highlights from the supply & demand analysis for Advanced Manufacturing skills. The objective of this presentation was to further set the scene for the workshop, collect initial expert feedback and frame the discussion.

2.1. *Reshaping Higher Education for Advanced Manufacturing: Mission Impossible?* Marte Andresen, PwC (Netherlands)

Ms. Marte Andresen presented the key outcomes of the online survey carried out in December 2018. In total, about 170 responses were collected from education & training providers, policy makers, companies and supporting organisations from all over Europe.

According to the survey respondents, the top three most important technical skills for the manufacturing professionals in the years to come include the ability to interact with human-machine interfaces (18%), data management skills (16%) and specialised knowledge of technologies and processes (16%). These findings confirm fundamental implications for the skill needs caused by the digital transformation of the manufacturing domain. As for the non-technical skills, the most important ones refer to adaptability/flexibility (19%), critical thinking (15%), creativity (13%) and general mind-set for continuous improvement and lifelong learning (13%). It is no longer mainly about what you know, but increasingly about if you are able to adapt to continuously changing circumstances and constantly advance your knowledge and skills.

The current initiative aims to produce **curriculum 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 eight dimensions will be considered by the **analytical framework**:

(1) **Strategy**: defining core values, commitments, opportunities, resources and capabilities of an educational/training institution;
(2) **Collaboration**: promoting practices that move beyond the typical institutional collaboration patterns and engaging individuals and communities;
(3) **Content**: defining the nature of educational content, including specific principles related to the actual content of the curricula;
(4) **Learning environment**: 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.;
(5) **Delivery mechanisms**: means by which learners experience and access education/training; special attention to technology-enabled learning;
(6) **Assessment**: identifying most appropriate forms of assessment, including advantages and disadvantages;
(7) **Recognition**: exploring appropriate formal and informal ways of recognition;
(8) **Quality**: identifying the determinants of education & training quality: what makes students' and employers' perception different?

As mentioned in the beginning of the workshop, the results of our pan-European online survey indicated that **the three elements of the AMT-related education & training system that require the most substantial change include**:

- **Strategy**: What are promising strategies and conceptual principles for developing a 21st Century curriculum for Advanced Manufacturing?
- **Collaboration**: What are promising collaboration practices for facilitating the exchange of knowledge and resources with a view to improve the educational offer for Advanced Manufacturing?
- **Learning environment**: What types of environment lead to the most effective learning for Advanced Manufacturing?

The three key directions for action that according to the survey responders would be most impactful in stimulating the required change in the current education & training system, include the following:

- **Regularly updating the skills of teachers/trainers**: sending the educational personnel to companies to get insights into the latest developments, while inviting people from companies to regularly teach in the classroom;
- **Actively involving companies** in the development and implementation of education & training curricula, including the identification of desired learning outcomes, curricula design, actual teaching/training, assessment and recognition;
- **Promoting innovation in teaching/training**: rewarding educational institutions and teachers/trainers for introducing innovative approaches; embedding these aspects in the assessment schemes for both organisations and individuals.

These points were followed by the need to **organise education & training around learners**, i.e. developing education & training ecosystems where learners and their needs are put in the centre, with the main focus on learning rather than teaching.

Finally, the **key types of content** that were suggested to be most valuable for the target group of the curriculum guidelines include good practice examples, key implementation challenges and possible solutions and conceptual curriculum design principles.

Ms. Marte Andresen also presented key findings from the AMT labour market analysis conducted in the context of the current initiative.

The analysis relies on several **key assumptions**. The definition of the AMT labour market in this analysis includes five (out of nine) occupations in manufacturing, as defined by Eurostat. Furthermore, growth in the labour market is assumed to follow the forecasts of Cedefop's Skills Forecast[7]. All estimates should be treated with caution, as the numbers are highly dependent on the assumptions and the approach used.

The results of the analysis suggest that the European AMT labour supply is expected to remain significantly higher than the corresponding demand. While there is variation between the EU Member States (MS), all MS (except Czech Republic) are forecasted to have continued excess labour supply in the coming years. This finding suggests that the objective should be not to increase the AMT labour supply, but rather to better align the skills with the requirements of the 21st Century.

Overall, a negative growth for lower skilled AMT-occupations is expected, while medium and high skilled occupations are forecasted to grow. However, large differences in the compositions of national labour markets

7 http://www.cedefop.europa.eu/en/publications-and-resources/data-visualisations/skills-forecast

signify a need for assessing requirements at lower levels. Hence, this initiative has developed an overview for each MS showing the estimated excess AMT labour supply at the occupational level in 2017 and 2026, and the required change in supply to balance the market in 2026.

2.2. *Discussion and feedback of participants*

Ms. Marte Andresen invited the workshop participants to express their feedback regarding the presentations given during the introductory session.

The key points of the discussion included the following:

- Teamwork skills were not considered as one of the most important elements for change by respondents of the online survey. In other reports, such as ‘Future of Jobs’ by the World Economic Forum, teamwork has a higher significance. It was discussed that a reason could be that while teamwork is considered important also within the ATM domain, it might not be considered as requiring the most substantial change and that other elements might more significantly lag behind.

- Changing structures in the labour market, such as changing forms of employment, might significantly influence both supply and demand of labour.

3. 21st Century Strategy, Collaboration Patterns and Learning Environment (Part 1)

The morning session continued with specific presentations featuring good practice examples with regard to the 21st Century Strategy, Collaboration Patters and Learning Environment. The session consisted of three presentations followed by a detailed discussion and feedback of participants.

3.1. *Platforms of Centres of Vocational Excellence*, Joao Santos, European Commission (Belgium)

Mr. *Joao Santos* presented the Platforms of Centres of Vocational Excellence.

VET policy makers are confronted with new challenges in anticipating and responding in due time to the fast changing skill needs of the labour market, and to the expectations of individuals. While change is not a new phenomenon, the speed of change is faster than ever. The “shelf-life” of skills is becoming increasingly short. To address this challenge, VET institutions must become much more flexible and responsive to the need for renewing their offer; companies have to become an active partner in designing and providing opportunities for work-based learning, and individuals have to embrace lifelong learning to maintain their employability, active citizenship and quality of life. The way we teach and learn has to be in tune with these new opportunities and challenges.

The speed and scale of change calls for innovative approaches where VET institutions are increasingly empowered to understand, engage and be an active partner in co-creating solutions for local social and economic development. A bottom-up approach to excellence where VET institutions are capable of rapidly adapting skills provision to evolving local needs is essential to raise the attractiveness, relevance and quality in VET.

To respond to this challenge, the European Commission is launching a new initiative on **Centres of Vocational Excellence (CoVE).** These are characterised by adopting a systemic approach through which VET institutions actively contribute to co-create “**skills ecosystems**”, together with a wide range of other local/regional partners. This initiative supports the establishment of CoVE’s that operate in a given local context, through **transnational cooperation platforms** that:

- bring CoVE’s that share a common interest in **specific sectors or trades** (e.g. aeronautics, e-mobility, green technologies, ICT, healthcare, tourism, etc.), or
- develop innovative approaches to tackle **societal, technological and economic challenges** (e.g. integration of migrants, Digitalisation, Artificial Intelligence, Sustainable Development Goals, upskilling people with skills and/or low qualification levels, etc.).

3.2. *Transforming learning and teaching in Higher Education for Advanced Manufacturing*, Lidia Borrell-Damián, European University Association (EUA) (Belgium)

Dr. Lidia Borrell-Damián presented Transformation of learning and teaching in higher education for advanced manufacturing, based on the experience of the European University Association (EUA).

The need for Advanced Manufacturing skills is influenced by a large spectre of drivers, including technological development, environmental change and changes is societal expectations. Consequently, the **transformation of learning and teaching in higher education is not happening in isolation**. Higher education for Advanced Manufacturing must consider aspects such as circular economy, energy transition and social transformations (such as gender equality and balance).

In collaboration with companies, EUA has identified skills requirement of industry and translated these to the context of universities. Building on this, the requirements for learning at universities in technical, social, economic and political aspects were developed.

There are four key considerations for the transformation of Higher Education for Advanced Manufacturing:

- Use of active learning to enhance learning outcome;
- University-business collaborations to close the gap between what universities teach and what companies require;
- Methodologies for knowledge management to lower threshold for constantly updating teaching content and making use of innovative approaches to teaching;
- Seeing Higher Education in the context of society to aligning university goals beyond research outcome.

3.3. *Designing engineering curricula based on the CDIO (Conceive-Design-Implement-Operate) approach*, Johan Malmqvist, Chalmers University of Technology (Sweden)

Prof. Johan Malmqvist presented the CDIO-approach to engineering curricula.

A modern engineering curriculum needs to prepare for engineering work **across the entire product, process and system lifecycle**, from identifying stakeholder needs to the ultimate retirement of the product, process or system. The CDIO approach is based on a detailed list of engineering competencies that engineering graduates should master upon graduation, along with twelve standards (effective practices) of engineering programmes that educate towards the CDIO competencies. The CDIO approach also provides a process and a set of tools for designing a CDIO-based programme, and for continuous improvement over time of the programme.

In the implementation of the CDIO-approach, it is important to first develop a high-level overview of the aspects the engineering education needs to include, **taking into account key drivers in technology and society, and defining programme learning outcomes**. Given this overview, universities must consider how these aspects are integrated in the curriculum. The preferred model in the CDIO-approach is the '**integrated curriculum'**, which is organised around disciplines, but with skills and projects interwoven.

Programme learning outcomes are defined in four categories: “Mathematics, science and engineering knowledge”, “Personal skills”, “Interpersonal skills” and “CDIO-skills”. For the success of the integrated curriculum model, it is essential that it is clearly defined which programme learning outcomes are covered in which courses.

If successful, CDIO programmes promote learning objectives not only for disciplinary knowledge, but also for personal and interpersonal skills. Furthermore, the approach is systematically designed to address all programme learning outcomes, often through applying integrated curriculum models.

3.4. Discussion and feedback of participants

Ms. Marte Andresen 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:

- Higher Education institutions are limited in terms of available resources, and access to machines for learning can be challenging. Higher Education should be seen as part of an educational chain and an educational ecosystem. How can universities collaborate with other parts of the chain or the ecosystem to both cover the gap and to shorten the change loops in Higher Education?

- Without proper infrastructure, we will never be able to follow the speed of change. Professors should not have to start from scratch when building programme curricula or a study course. Accessible, open source material would help. We should not underestimate the effort of finding, adopting and tailoring new material.

- Many good initiatives come bottom-up in Higher Education. However, if there is no top-down coordination, then no systematic change will happen. There is a need to facilitate systematic change in Higher Education, while keeping good ideas and initiatives coming from the ones who are most active in teaching. In order to succeed, we need commitment from both higher and lower levels of the organisation. Professors should be committed to the defined learning outcomes and deliver quality in teaching, while there is also a need for a committed programme head responsible for the whole picture.

- Technological development is not happening on its own, but it is driven by innovative research and industry. For education to be future oriented, we must invest resources in the design and provision of curricula.

- It is important not to see any solution in isolation. We need to have a holistic approach with a spectrum of (improved) instruments to enhance Higher Education in the domain of Advanced Manufacturing and to improve the competitiveness of the European industry.

4. 21st Century Strategy, Collaboration Patterns and Learning Environment (Part 2)

The afternoon session continued with specific presentations featuring good practice examples with regard to the 21st Century Strategy, Collaboration Patters and Learning Environment. The session consisted of eight presentations followed by a detailed discussion and feedback of participants.

4.1. *Making Analytics Come Alive with Digital Twins: Hands-on Experience in the Higher Education*, Jivka Ovtcharova, Karlsruhe Institute of Technology (KIT) (Germany)

Prof. Jivka Ovtcharova presented the notion of digital twin, and the use and hands-on experience in Higher Education.

The notion of a “digital twin” is now being widely adopted and it is rapidly becoming the technology of choice for virtualising the physical world. As versatile and powerful as digital technologies may be, the original purpose of the digital twin remains unchanged: **to enable humans to face problems easily, get to the point, understand, and proceed pragmatically and rapidly**. The "Internet of Things" becomes the "Internet of Twins" strengthening the “front-end” of all we do, to make it more dynamic, and to make learning highly interactive. The digital twin offers us opportunities to inquire the unexpected and to discover the best, and make decisions based on up-to-date, transparent information.

A use case of a digital twin of a milling machine for process optimisation and networking in virtual reality, taking account of resource flows, demonstrates **how to reshape the Higher Education and how to obtain practical skills**. All solutions that are linked to the management of complex and large data sets, e.g. data accumulated in engineering practice, lead to the digital twin’s approach “reducing complexity” to simplify decision-making processes.

Implementing digital twin requires putting real problems “in the sandbox“ of business units, think, try out, create “all-in-one“, apply emerging digital technologies playfully and quickly and test new solutions in runtime to gain experiences fast and to transform knowledge into actions and skills.

4.2. *Student-centred learning in practice*, Monika Skadborg, European Students’ Union (Denmark)

Ms. Monika Skadborg addressed the notion of student-centred learning from students’ perspective.

Student-centred learning (SCL) is about considering students as full and equal partners in their own learning, and moving away from seeing them as consumers or empty vessels to be filled. The purpose of learning can be stated to be supply of the labour force, and preserving and developing knowledge. SCL uses the radical notion that the **purpose of education is learning**, and education is also a personal transformation.

European Students’ Union (ESU) uses the following definition for SCL: “Student-centred learning represents both a **mind-set and a culture** within a given higher education institution and is a **learning approach** which is broadly related to, and supported by, constructivist theories of learning. It is characterised by **innovative methods of teaching** which aim to promote learning in **communication with teachers and**

other learners and which take students seriously as **active participants in their own learning**, fostering transferable skills such as problem-solving, critical thinking and reflective thinking."

In order to succeed with SCL, there is a need for **flexibility and freedom of learning**. Further **clear, mutual expectations and open communication** between equal partners in education are essential to actually allow students to be the centre of education. Finally, there is a need to invest in **training of teachers** allowing them to remain hands-on and up-to-date on developments in technology and industry.

4.3. *Product Development Lab: Innovative Design and Advanced Manufacturing student training*, Manuel Freitas, MIT Portugal (Portugal)

Prof. Manuel Freitas reviewed the experiences gained within the research and education program MITPortugal, under the focus area of Engineering Design and Advanced Manufacturing (EDAM) (2006-2014).

The EDAM mission was 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.

A partnership of multiple stakeholders has led to the creation of a Design Studio followed by Product Development laboratories, where engineering students developed their final curricula work with the use of new technologies. It was found to be an excellent educational path to teach engineering design and product development at Bachelor and Master levels. In Engineering Design and Product Development, subjects like creativity, innovative materials, new technologies and cost models have to be present in order to evaluate the feasibility of the product.

Through project-based learning, engineering students jointly developed new multidisciplinary ideas and innovative products, with the application of new technologies that help to complement the basic formation in engineering.

4.4. *Problem- and project based learning environments at course and system level*, Anette Kolmos, Aalborg Centre for Problem-Based Learning in Engineering Science and Sustainability, Aalborg University (Denmark)

Prof. Anette Kolmos presented the notion of problem-based learning (PBL) and the need for an educational leadership.

Currently, the PBL-approach is implemented in some courses or selective parts of a study programme. This approach does not enhance learning outcomes, and it becomes exhausting for students, who have to manage multiple projects simultaneously. A more promising approach is to **coordinate PBL across several disciplines**, in shared projects where students have to apply a variety of different skills. However, in order to succeed, there is a strong need for educational leadership.

To enhance the outcome of learning, collaboration with external partners is essential. There are **several layers of collaboration**: company as informant, company as case, company as client and company as project partner.

Different challenges and solutions create different requirements for learning models. Highly complex problems and solutions require interdisciplinary knowledge and competences. Consequently, the curriculum will need to be reorganised around new student-centred and blended learning models, with problem-based projects across disciplines and together with stakeholders.

4.5. *Advanced manufacturing challenges & Dual Training and Engineering*, Aintzane Conde, The Machine Tool Institute IMH (Spain)

Dr. Aintzane Conde presented the Dual System Learning based on the experience from the Basque Country.

The Dual System Learning Method provides the needed connection between companies, students and educational institutions. The philosophy focuses on what students should learn, but just as much on how to learn. From Vocational Training up to Master Degree, without forgetting life-long learning, which could become a key point in order to fulfil companies expectations about the rapidly development of the industry and technologies.

In a systematic way, aided by tools and best practices, students interact with companies and the educational institution obtaining academic knowledge and practical experience during, at least, 75 % of their study period. In addition, companies interact with the educational institutions ensuring that education is in fact aligned with the regional needs.

The Machine-Tool Institute has the experience of more than 20 years of Dual System Education that would bring a different point of view, focusing on “how” the institutions should teach instead of “what” the students learn, based on the increasing speed of change in industry and development. Moreover, their experience developing industrial projects for companies ensure this connection to bring to the companies the workers they want, in any point of their career.

4.6. *FCT-NOVA Curriculum approach: Connecting engineering students with the industrial environment*, Marco Leite, Faculdade de Ciência e Tecnologia da Universidade Nova de Lisboa (Portugal)

Prof. Marco Leite presented experiences from the Faculty of Sciences and Technology (FCT) at the University of Lisbon and the success of connecting engineering students with the industrial environment.

In order to enhance student education with training in **transversal skills**, FCT introduced these skills into the curricular structures of all BSc, MSc and integrated MSc, thus creating the “FCT Curricular Profile”.

In their third year, students have the “Introduction to Professional Practice”, where students have contact with industry in an area relevant to the degree programme, through **internships and short-term work**. Results show that both students and companies benefit from this course. Students get real life experience, observe engineers in real life projects and share their experience with peers. Companies benefit from this experience in several ways. It allows companies to intervene in the formation of future engineers; some students return to the company to develop their master thesis and companies get engineering tasks solved by students.

A key success factor is the engaging students in finding internships, ensuring that they have an active relationship with the company. Furthermore, FCT has established a shared online portal for administering contacts between professors, students and companies.

4.7. *Creativity for AM: An Industrial Design perspective*, Jouke Verlinden, University of Antwerp (Belgium)

Prof. Jouke Verlinden shared experiences of teaching academic level courses in Advanced Manufacturing and digital fabrication in the field of product design.

The **Human-Centred Digital Fabrication** consists of the following elements: Production processes, Product (i.e. characteristics and heritage) and Human (user, designer and worker). Often too little attention is put on the last two elements.

Collaboration should go beyond the classroom, and Higher Education should embrace field labs or innovation hubs, yet from an academic perspective, often in partnership with industry and with limited lifespan. This is a promising way to do research and to engage students.

To enhance learning in Higher Education for Advanced Manufacturing, one could offer at least 50% high-tech systems, challenge students to construct new systems (rather than applying existing ones), be multidisciplinary by design, identify and embrace local and international heroes, and finally have a blended learning approach with elements of both online and offline learning.

4.8. *Virtual Learning Factory Toolkit*, Marcello Urgo, Politecnico di Milano (Italy)

Dr. Marcello Urgo presented the Virtual Learning Factory Toolkit (VLFT) project.

The VLFT focuses on the development and integration of a set of **digital tools to support advanced engineering education in manufacturing**. The aim is to bring back to the engineering students the results of research activities in the field of digital manufacturing, i.e., modelling, performance evaluation, virtual and augmented reality, as well as the role of human workers in factories. The digital tools in the VLFT will provide the following functionalities:

- Digital tools for production system design;
- Digital tools for exploiting virtual and augmented reality in manufacturing;
- Digital tools for human modelling in manufacturing;
- An integrated user interface.

Students involved in this initiative will take part in a project work phase in groups from three universities, **collaborating across distance to cope with a specific task** (e.g., test a digital tool, define and formalise workflows, document application cases, develop new functionalities). Furthermore, they will have a **Joint Learning Lab** for five days to test and demonstrate the digital tools through the application to one or more application cases. The lab is organised each year at one of the partner universities.

The results of the Virtual Learning Factory Toolkit project will be disseminated through:

- A guideline for the use of the digital tools in the Advanced Manufacturing education;
- An open-source Digital Factory Framework to provide a common modelling framework;
- A set of digital tools available for free to universities and education bodies for non-profit utilisation.

4.9. *Discussion and feedback of participants*

Ms. Marte Andresen 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:

- Student-centred learning is not a one size fits all approach. One must tailor the learning to individual students, and it requires proper guidance and points back to the role of communication between teachers and students. Digital tools can help, but should not replace student-teacher interaction. Blended learning is a promising approach.

- Sustainability is important for student, but less often included in study programmes. Sustainability refers to both disciplinary knowledge and professional competence. Everyone should have an opportunity to choose a master specialisation in sustainability. Problem-based learning is also one way of including more sustainability in a study programme by selecting relevant problems. Furthermore, sustainability should also be an element of the continuing on-the-job training, in the same category as health and risks.

- Most engineering study programmes today miss the social aspect, enabling students to understand social implication of new technologies.

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 workshop participants were invited to submit their suggestions and share their experiences with regard to each of the abovementioned elements of the curriculum guidelines.

5.2. Next steps

Mr. André Richier encouraged the participants to continue sharing their insights and suggestions for this initiative. He also pointed out the importance of involving students and younger generations in enhancing Higher Education for Advanced Manufacturing.

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 participants were also encouraged to join the initiative's LinkedIn-group that can be found at https://www.linkedin.com/groups/8689260/.

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), Marte Andresen (PwC)*
10:30 - 11:00	**Reshaping Higher Education for Advanced Manufacturing: Mission impossible?** • Results of the online survey (end of 2018) • Update on the Curriculum Guidelines Framework • Highlights of supply & demand analysis for Advanced Manufacturing skills	*Marte Andresen (PwC), Naveen Srivatsav (PwC)*
11:00 - 12:00	**21st Century Strategy, Collaboration Patterns and Learning Environment (Part 1)** • **Platforms of Centres of Vocational Excellence**, *Joao Santos*, European Commission (Belgium) • **Transforming learning and teaching in Higher Education for Advanced Manufacturing**, *Lidia Borrell-Damián*, European University Association (EUA) (Belgium) • **Designing engineering curricula based on the CDIO (Conceive-Design-Implement-Operate) approach**, *Johan Malmqvist*, Chalmers University of Technology (Sweden)	*Moderators: Marte Andresen (PwC), Naveen Srivatsav (PwC)*
12:00 - 12:30	**Discussion and feedback of participants**	*Moderators: Marte Andresen (PwC), Naveen Srivatsav (PwC)*
12:30 – 13:00	**LUNCH BREAK**	
13:00 - 15:00	**21st Century Strategy, Collaboration Patterns and Learning Environment (Part 2)** • **Making Analytics Come Alive with Digital Twins: Hands-on Experience in the Higher Education**, *Jivka Ovtcharova*, Karlsruhe Institute of Technology (KIT) (Germany) • **Student-centred learning in practice**,	*Moderators: Marte Andresen (PwC), Naveen Srivatsav (PwC)*

	Monika Skadborg, European Students' Union (Denmark) • **Product Development Lab: Innovative Design and Advanced Manufacturing student training**, *Manuel Freitas*, MIT Portugal (Portugal) • **Problem- and project based learning environments at course and system level**, *Anette Kolmos*, Aalborg Centre for Problem-Based Learning in Engineering Science and Sustainability, Aalborg University (Denmark) • **Advanced manufacturing challenges & Dual Training and Engineering**, *Aintzane Conde*, The Machine Tool Institute IMH (Spain) • **FCT-NOVA Curriculum approach: Connecting engineering students with the industrial environment**, *Marco Leite*, Faculdade de Ciência e Tecnologia da Universidade Nova de Lisboa (Portugal) • **Creativity for AM: An Industrial Design perspective**, *Jouke Verlinden*, University of Antwerp (Belgium) • **Virtual Learning Factory Toolkit**, *Marcello Urgo*, Politecnico di Milano (Italy)	
15:00 – 15:30	**Discussion and feedback of participants**	*Moderators: Marte Andresen (PwC), Naveen Srivatsav (PwC)*
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), Marte Andresen (PwC)*

Annex B: Workshop participants

Nr	Name	Organisation	Country
1.	*Joao Santos*	European Commission, DG EMPL	Belgium
2.	*Lidia Borrell-Damián*	European University Association (EUA)	Belgium
3.	*Johan Malmqvist*	Chalmers University of Technology	Sweden
4.	*Monika Skadborg*	European Students' Union	Denmark
5.	*Anette Kolmos*	Aalborg University	Denmark
6.	*Aintzane Conde*	The Machine Tool Institute IMH	Spain
7.	*Marco Leite*	Faculdade de Ciência e Tecnologia da Universidade Nova de Lisboa	Portugal
8.	*Jouke Verlinden*	University of Antwerp	Belgium
9.	*Jivka Ovtcharova*	Karlsruhe Institute of Technology (KIT)	Germany
10.	*Marcello Urgo*	Politecnico di Milano	Italy
11.	*Manuel Freitas*	MIT Portugal	Portugal
12.	*Ahmad Bsiesy*	CIME Nanotech	France
13.	*Jouni Partanen*	Aalto University	Finland
14.	*Vincenzo Renda*	CECIMO	Belgium
15.	*Roger De Keersmaecker*	RDK Consulting & Coaching	Belgium
16.	*Daniel Brissaud*	Grenoble Institute of Technology	France
17.	*Valerie Rocchi*	Grenoble Institute of Technology	France
18.	*Mohammad Ghaemi Nia*	TU Delft	Netherlands
19.	*Paula Queipo Rodríguez*	Idonial	Spain
20.	*Giovanni Crisona*	SkillMan	Italy
21.	*Emir Demircan*	SEMI-Europe	Belgium
22.	*André Richier*	European Commission, DG GROW	Belgium
23.	*Evangelos Meles*	European Commission, DG GROW	Belgium

Nr	*Name*	*Organisation*	*Country*
24.	*Ana Grigore*	European Commission, DG RTD	Belgium
25.	*Giovanna D'Addamio*	EASME	Belgium
26.	*Marte Andresen*	PwC	Netherlands
27.	*Naveen Srivatsav*	PwC	Netherlands