The 21st Century Students Project - Promoting Digital Manufacturing and Design in European Schools, towards the Fourth Industrial Revolution

The present work presents the activities which are performed in the "21st Century students" project. The main target of this project is to assist students to improve their Science, Technology, Engineering, and Mathematics (STEM) skills through digital manufacturing and design, in response to Industry 4.0. The primary target group of the project is Key Stage (KS) 3 students and their educators. The "21st Century students" project is implemented through a close collaboration of partners from various European countries, providing complementary backgrounds, aiming to:

- *Create a transnational network of 7 educators and digital manufacturing experts to promote effectively STEM learning in school's sector.*
- *Prepare students for Industry 4.0 revolution, developing a Learners Academy, that is focused on attributing to pupils expert-led learning experiences on Digital Modelling, Fabrication, and Automation.*
- *Develop an open Digital Manufacturing Learning Lab to support the effective delivery of education both within and beyond the classroom and support groups of educators to grow their skills.*
- *Strengthen the capacity of all organizations working in secondary education to provide quality STEM knowledge, thus enabling them to lead the way in Industry 4.0 education.*

Keywords: *STEM education, Industry 4.0, Digital Manufacturing, Digital Design, Digital Fabrication*

Introduction

The relatively low attractiveness of Science, Technology, Engineering, and Mathematics (STEM) studies and careers, and the demanding labor-market needs in STEM-related disciplines raise a challenge throughout Europe. The number of STEM students has been dwindling in recent years. Since 2000, the rate of European graduates in STEM disciplines has been reduced by 3%, as a result of the common perception that STEM subjects are too difficult or complex (Scientix, 2016). As we move on to the fourth industrial revolution (Industry 4.0), manufacturing companies are rapidly harnessing revolutionary digital design, fabrication, and automation technologies. Cutting-edge and new manufacturing techniques and tools are continuously introduced to industry, exerting extra pressure on educators to remain agile and industry relevant in a continuously changing environment.

This gap between education and the labor market is exacerbated by limited innovation in learning systems and inability to keep up with the pace of advances in industry. Without any action the next generation will be unprepared for the needs of the future, risking both productivity and social cohesion. According to the

World Economic Forum (World Economic Forum,2018, there is a growing disconnect between education systems and labour markets, and many of today's children will work in new job types that do not yet exist. Subsequently, the 'Education 4.0' initiative calling was launched for all stakeholders to act in transforming the primary & secondary education system.

Thus, focus is needed on shifting the content of learning and the mechanisms through which it is delivered, to meet the needs of the future; hence, to upskill also the teachers whose adaptation will have a multiplier effect on next generation. To cope with the fast pace of technological innovation, education systems need to foster deeper and more diverse partnerships to drive curriculum and, most importantly, pedagogical innovations in favour or Science, Technology, Engineering, and Mathematics (STEM) (Scientix, 2018) and to ensure nations can supply a sufficient talent pipeline for the technologically orientated careers of the future, providing the necessary flexibility for economy in order to cope with the continuous technological advancements and challenges.

The "21st Century students" project moves towards this direction. It is grounded on the premise that students of all abilities can improve their STEM skills through digital manufacturing and design (DM&D), in response to cover the needs and challenges of Industry 4.0 (Lee et al., 2018), being prepared for a rapidly developing digital-driven world of work. The project fosters the creativity and innovation skills of pupils, mainly through hands-on and technology-based digital manufacturing tools, to drive STEM education in non-conventional ways. The project promotes teaching experiences that are aligned to the modern workplace, by the use of technologies and tools that are endemic to Industry 4.0. It will create novel teaching resources and professional development materials to support the schools sector to keep up with the pace of advances in manufacturing, facilitating the use and comprehension of digital tools. In the long term this will contribute significantly to the maintenance of the European manufacturing industry strong position globally, which currently accounts for almost 15% of the EUs GDP (Eurostat 2018).

Previous Erasmus+ KA2 projects on the theme of Digital Manufacturing & Design are largely focused on the Vocational Education and Training (VET) sector and often did not fully succeed to encourage schools to also embrace alternative models of instruction and learning in support of ascertaining 'Education 4.0'. Although there is a realization that education needs to develop students to meet the challenges and needs of today industry and society, projects did not fully succeed to recognize the value of early integration of practical and enjoyable DM&D learning experiences as a support tool to raise students' interest in STEM subjects. Previous KA2 projects such as the 'European Robotic Laboratory' (2014-1-FR01-KA201-008671) and 'ERASMUS3D+: Training material for developing 3D printers' (2015-1-DE02-KA202-002496) contain elements useful for this project through the provision of in-depth educational materials for upskilling learners in the area of Robotics and 3D printing. However, they presented an element of 'over-specialization' and could not fully provide a holistic educational package aimed at promoting a basic understanding of a variety of Digital Manufacturing technologies.

The 21st Century partnership is aligned to the opinion that school students would benefit more from a wider range of introductory resource focused on the various technologies associated with Digital Modelling, Digital Fabrication and Manufacturing Automation. 21st Century Students encapsulates and builds on previous good practice but seeks to go further through the creation of an Intellectual Output (IO) ‘Learning Academy’ (IO1) that will provide a suite of ‘taster’ teaching resources categorized across the following three thematic ‘mini toolkits’: Digital Design, Digital Fabrication and Manufacturing Automation. This will be supported by the Intellectual Output ‘Digital Manufacturing Learning Lab’ (IO2) acting as an openly accessible platform to support the effective delivery of DM&D education both within and beyond the classroom learning environment. Schools leaders will be supported in the implementation of the ‘21st Century Student’ resources, through the creation of the Intellectual Output ‘Implementation Handbook’ (IO3) and the Intellectual Output ‘Teachers 4.0 – Training Programme’ (IO4) which will provide both the pedagogical and technical skills required to use DM&D technologies as a tool to raise students’ interest in STEM subjects, and confidently endorse the concepts of “learning by doing” and “flipped classroom ”approaches.

Aims and Objectives

Driven by the rapidly changing needs of employers and the demand for new skills for the fourth industrial revolution, ‘21st Century Students’ will place a premium on motivating students to become ‘creators’ and ‘innovators’ through exposure to high-tech digital manufacturing facilities and expertise. The “21st Century students” project relinquishes the classical approach that the educator is the only source of information, and the classroom is the only place where knowledge can be disseminated. It endorses a technology-based and student-centric approach that enables pupils to learn from different sources and educators than what they were traditionally exposed to. The primary target group of the project is Key Stage 3 students and their educators. The “21st Century students” project is implemented through a close collaboration of partners from various European countries, providing complementary backgrounds, aiming to:

- ✓ Create a transnational network of 7 educators and digital manufacturing experts to promote effectively STEM learning in school’s sector, working collaboratively to promote effective STEM learning in the schools sector, subsequently driving the skills and capabilities required to deal with industrial complexities..
- ✓ Prepare students for Industry 4.0 revolution, through the development of a 21st Century Students ‘Learner Academy’, focused on exposing school students to digital manufacturing environments and expert-led learning experiences on Digital Modelling, Fabrication and Automation.
- ✓ Develop an open Digital Manufacturing Learning Lab to support the effective delivery of DM&D education both within and beyond the

classroom learning environment and provide a forum for supporting groups of educators to grow their craft in collaboration with one another.

- ✓ Strengthen the capacity of all organizations working in secondary education to provide quality STEM knowledge, thus enabling them to lead the way in Industry 4.0 education & meet the needs of an increasingly digital manufacturing sector.

Methodology/Direct project Implementation

The 21st Century Student project direct implementation includes four Intellectual Outputs, six multiplier events and a range of various dissemination activities. Each of the above will directly target individuals to a new understanding of different perspectives and approaches in STEM education, and on the impact of using practical Digital Manufacturing & Design technologies as a support tool to raise students' interest in STEM subjects.

More specifically, details for each one of the mains activities are presented below for each one of the Intellectual Outputs.

- Intellectual Output IO1: 21st Century Students: Learner Academy
    - IO1 will undertake data collection with 120 industry leaders across 6 EU countries to determine the primary Industry 4.0 skills and techniques required by the future talent pipeline to support the next generation of industrial revolution. This will ensure the pedagogical resources designed for the 'Learner Academy' are demand-led and guided by the latest industry thinking.
    - Infographic Report: summarizing the fundamental 'Industry 4.0 skills' required for future STEM employees in the contemporary manufacturing sector. This data will be collected through a primary research exercise with 120 manufacturing experts from across the six partner countries.
    - A collection of 30 'taster teaching resources' categorized in three thematic 'mini toolkits': Digital Design, Digital Fabrication and Manufacturing Automation will be created.
    - IO1 will pilot the 3 toolkits that constitute the Learner Academy to 150 KS3 students (30 per DM&D facility). The project consortium partners will reach out to their secondary school network or relevant platforms to recruit 30 KS3 learners to participate in 'Experience Days' in which they will gain first – hand experiences with the latest DM&D equipment, resources, and expertise. The 150 learners will evaluate the 'Learner Academy' resources following the pilot to inform the continuous refinement & development of the resources prior to going 'live' on the 'Digital Manufacturing Learning Lab' in Intellectual Output IO2.
- Intellectual Output IO2: Digital Manufacturing Learning Lab
    - In IO2 school leaders will have the opportunity to voice their ideas and opinions for the final design of the Digital Manufacturing Learning Lab through a feedback session coordinated by all partners following the initial

    conceptual design of the online platform. This will be completed prior to the technical development.
  - An openly accessible platform will support the effective delivery of DM&D education both within and beyond the classroom learning environment and provide a forum for supporting groups of educators to grow their craft for STEM education in collaboration with one another.
  - In IO2 120 school educators across 6 EU countries will be involved in the Learning Lab pilot through live demonstration sessions to gauge feedback on usability from an educators perspective.
  - The learning lab will be disseminated to 350 school educators (50 per partner).
- Intellectual Output IO3: 21st Century Students: Implementation Handbook
  - In IO3 a 'how-to' manual providing the nuts and bolts for implementing the 21st Century pedagogical resources and online tools will be created and piloted to 120 school educators. A group of 20 educators in each of the 6 partner countries will be conducted to assess the guidance on materials, planning & delivery both within and outside the classroom. The Implementation Handbook will also provide the technical guidelines for using the 'Digital Manufacturing Learning Lab'. The intended audience includes program leaders, teachers, and instructional staff working to adapt and implement the 21st Century Student resources, and wider STEM initiatives.
- Intellectual Output IO4: Teacher 4.0 Training Programme
  - In IO4 60 school educators will participate in the pilot of the 'Teacher 4.0' teacher training programme which will consist of both technical and pedagogical CPD to ensure teachers have the correct theoretical and practical skills to deliver effective DM&D education. This will focus on the use DM&D technologies as a tool to raise students' interest in STEM subjects, and confidently endorse the concepts of "learning by doing" and "flipped classroom" approaches.

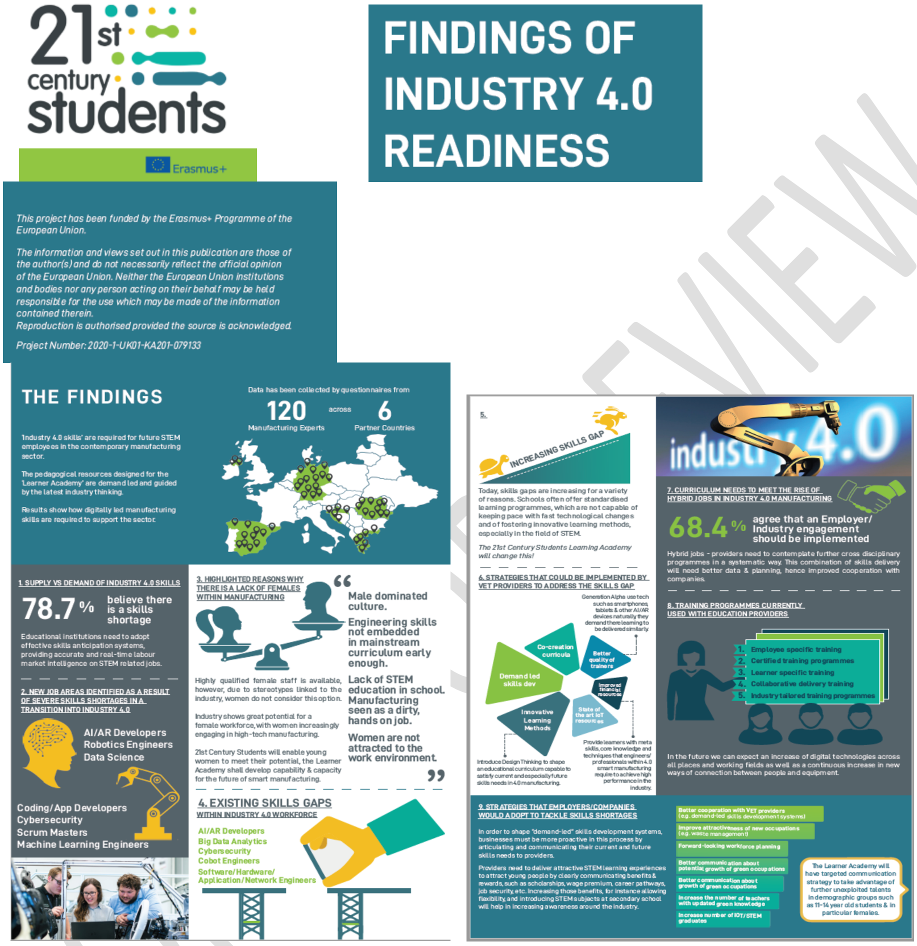
It worths to be mentioned that in order to efficiently cover the requirements and needs for the preparation of the above-mentioned Intellectual Outputs, the '21st Century Students' consortium combines partners of different, yet complementary backgrounds, that bring in the project the following advantages:

- Latest expertise and facilities in digital design & manufacturing
- Schools educators with access to digital fabrication laboratories
- Close links to school networks
- Experience working with industry stakeholders to identify future skills requirements in the Manufacturing Sector
- Excellence in the design and delivery of professional development programs of STEM education
- Geographical coverage to ensure a transnational approach.
- Designing digitally based pedagogical resource development and deployment.

Methodology/Examples of the created Educational Resources

In the following figures, an indicative presentation of typical examples of the Intellectual Outputs resources (in the form of PowerPoint detailed presentations) are presented below is shown.

Figure 1. *Infographic Report summarizing the fundamental Industry 4.0 STEM required skills (IO1)*



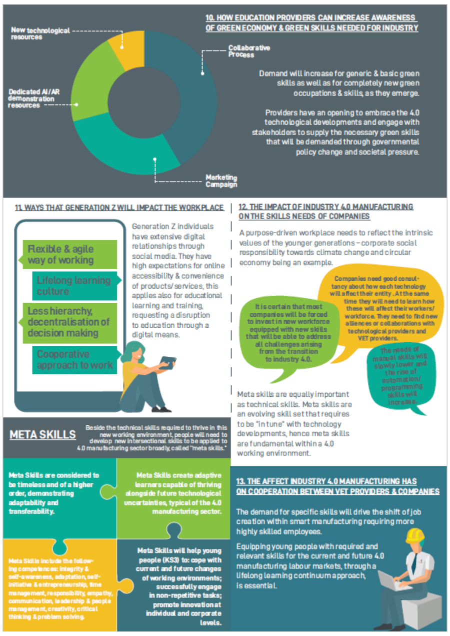
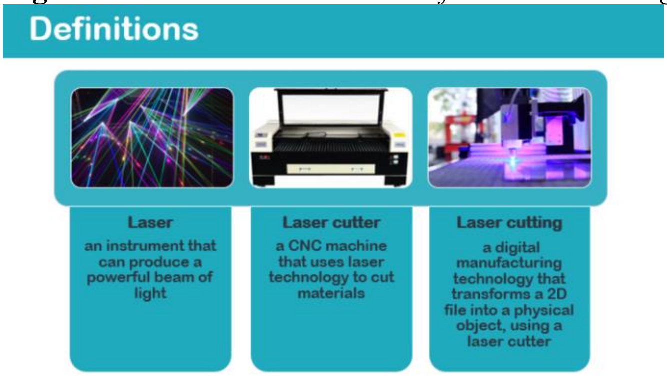

10. HOW EDUCATION PROVIDERS CAN INCREASE AWARENESS OF GREEN ECONOMY & GREEN SKILLS NEEDED FOR INDUSTRY
New technological resources
Collaborative Process
Dedicated AI/AR demonstration resources
Marketing Campaign
Demand will increase for generic & basic green skills as well as for completely new green occupations & skills, as they emerge.
Providers have an opening to embrace the 4.0 technological developments and engage with stakeholders to supply the necessary green skills that will be demanded through governmental policy change and societal pressure.
11. WAYS THAT GENERATION Z WILL IMPACT THE WORKPLACE
Flexible & agile way of working
Lifelong learning culture
Less hierarchy, decentralisation of decision making
Cooperative approach to work
Generation Z individuals have extensive digital relationships through social media. They have high expectations for online accessibility & convenience of products/services, this applies also for educational learning and training, requesting a disruption to education through a digital means.
12. THE IMPACT OF INDUSTRY 4.0 MANUFACTURING ON THE SKILLS NEEDS OF COMPANIES
A purpose-driven workplace needs to reflect the intrinsic values of the younger generations – corporate social responsibility towards climate change and circular economy being an example.
Companies need good consultancy about how each technology will affect their entity. At the same time they will need to learn how these will affect their workers/workforce. They need to find new alliences or collaborations with technological providers and VET providers.
It is certain that most companies will be forced to invest in new workforce equipped with new skills that will be able to address all challenges arising from the transition to industry 4.0.
The needs of manual skills will slowly lower and the rise of automation/programming skills will increase.
Meta skills are equally important as technical skills. Meta skills are an evolving skill set that requires to be "in tune" with technology developments, hence meta skills are fundamental within a 4.0 working environment.
META SKILLS
Beside the technical skills required to thrive in this new working environment, people will need to develop new intersectional skills to be applied to 4.0 manufacturing sector broadly, called "meta skills."
Meta Skills are considered to be timeless and of a higher order, demonstrating adaptability and transferability.
Meta Skills create adaptive learners capable of thriving alongside future technological uncertainties, typical of the 4.0 manufacturing sector.
Meta Skills include the following competences: integrity & self-awareness, adaptation, self-initiative & entrepreneurship, time management, responsibility, empathy, communication, leadership & people management, creativity, critical thinking & problem solving.
Meta Skills will help young people (KS3) to: cope with current and future changes of working environments; successfully engage in non-repetitive tasks; promote innovation at individual and corporate levels.
13. THE AFFECT INDUSTRY 4.0 MANUFACTURING HAS ON COOPERATION BETWEEN VET PROVIDERS & COMPANIES
The demand for specific skills will drive the shift of job creation within smart manufacturing requiring more highly skilled employees.
Equipping young people with required and relevant skills for the current and future 4.0 manufacturing labour markets, through a lifelong learning continuum approach, is essential.

Figure 2. *Indicative screenshots of the 3D Printing in Manufacturing resource (IO1)*

Figure 3. *Indicative screenshots of the Laser cutting resource (IO1)*



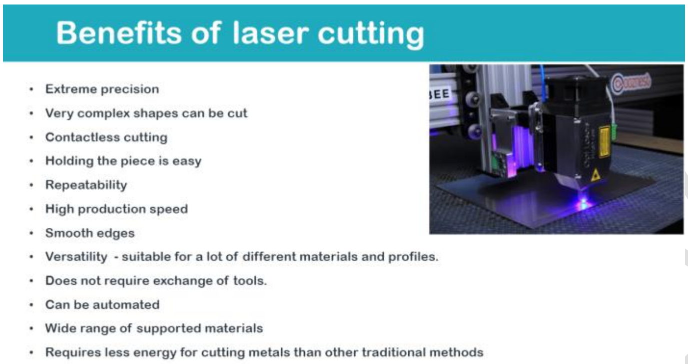
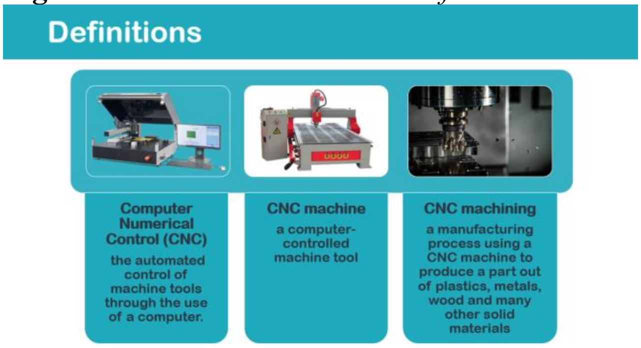
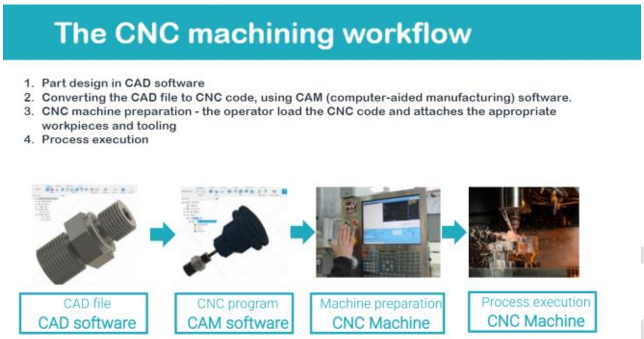


Figure 4. *Indicative screenshots of the CNC machining resource (IO1)*





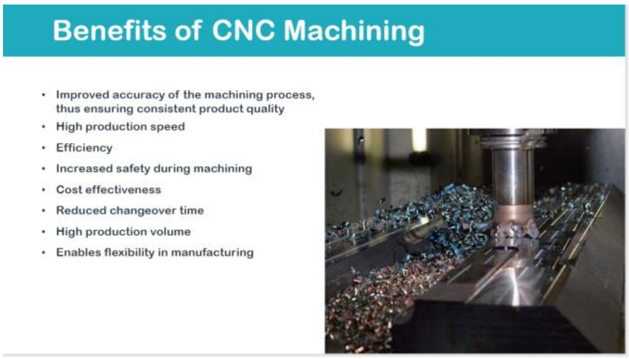
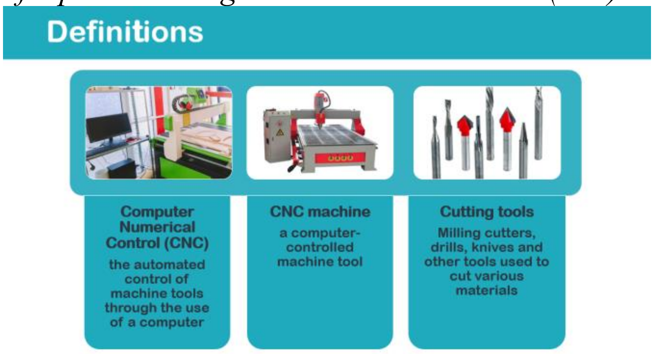
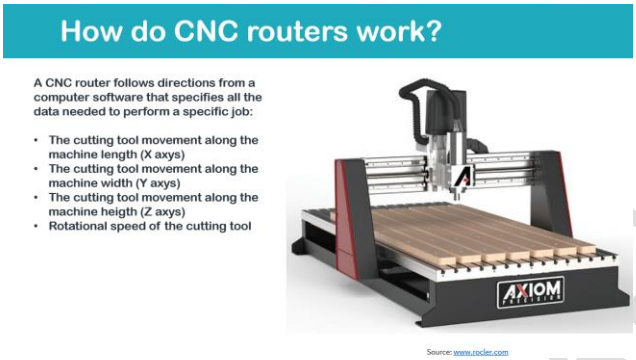


Figure 5. *Indicative screenshots of the CNC routing – Digital manufacturing of a product using a CNC router resource (IO1)*





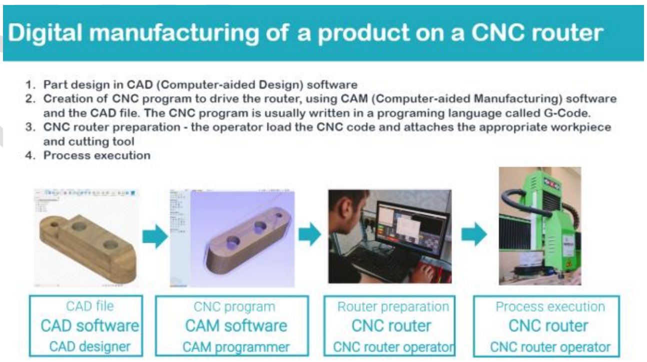
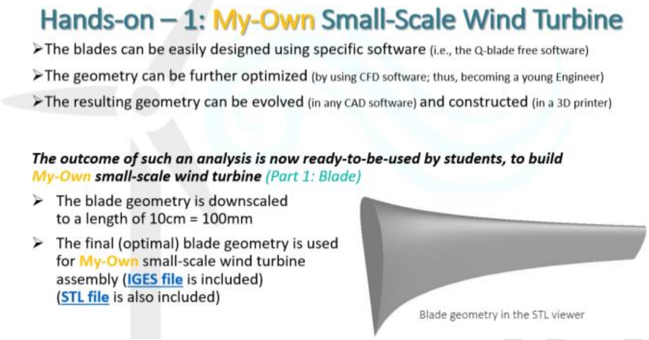


Figure 6. *Indicative screenshots of the Digital Fabrication-Digital evaluation of an aircraft design resource (IO1)*

Figure 7. *Indicative screenshots of the Digital Fabrication-Wind turbine digital fabrication resource (IO1)*



21st century students

DIGITAL FABRICATION

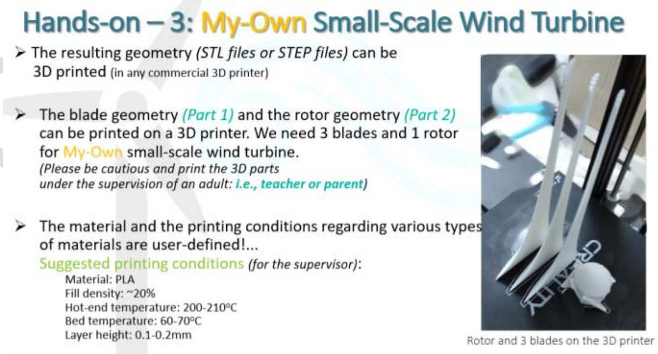
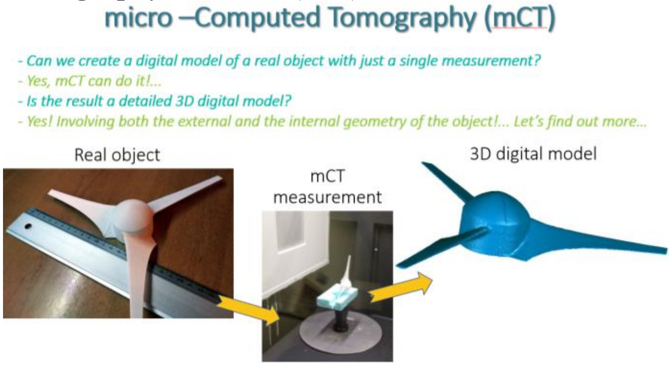
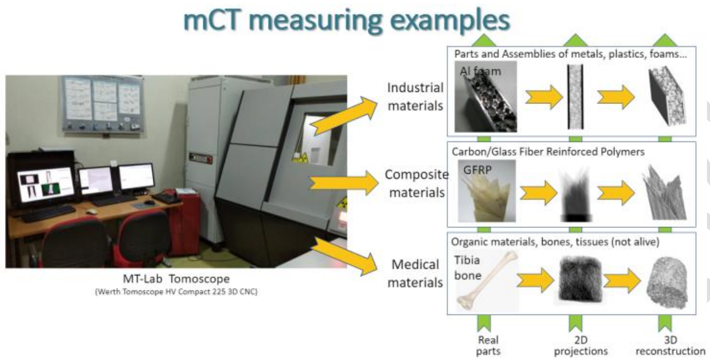


Figure 8. *Indicative screenshots of the Digital Fabrication-micro-Computed Tomography resource (IO1)*





21st century students

DIGITAL FABRICATION

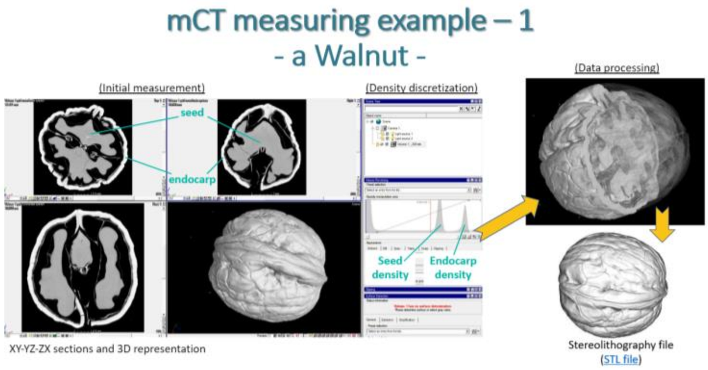
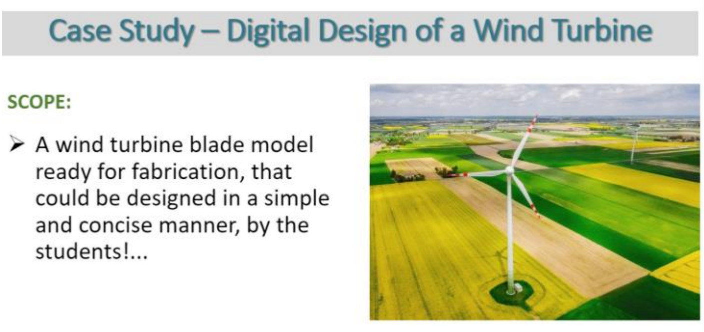
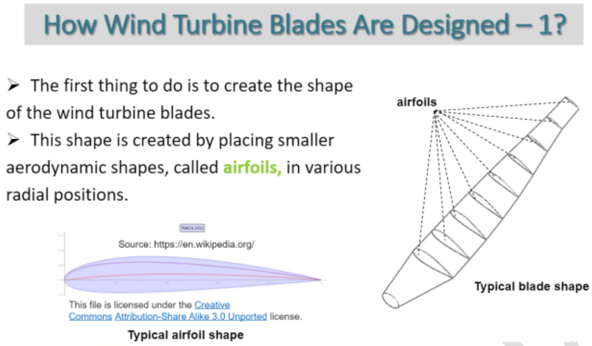


Figure 9. *Indicative screenshots of the Digital Fabrication-Digital Design of a Wind Turbine resource (IO1)*





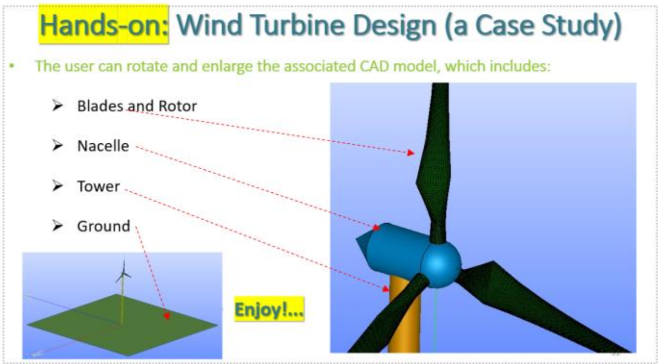


Figure 10. *Indicative screenshots of the Digital Design-CAD Practical resource (IO1)*

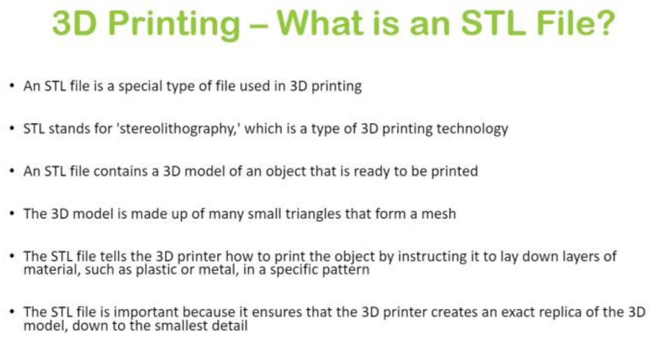
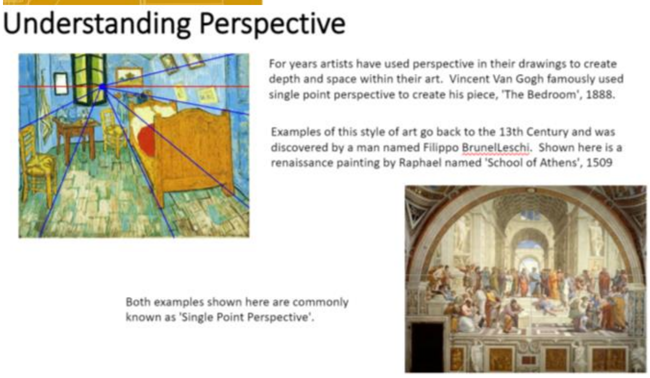


Figure 11. *Indicative screenshots of the Digital Design-CAD intro resource (IO1)*

Figure 12. *Indicative screenshots of the Digital Design-Drawing Practical resource (IO1)*



21st century students

Drawing Practical

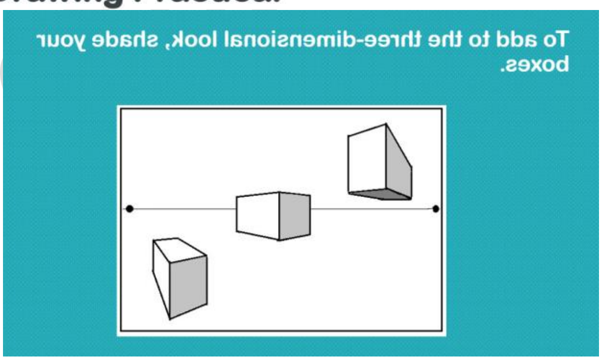


Figure 13. *Indicative screenshots of the Manufacturing automation-Intro to Manufacturing automation resource (IO1)*

Figure 14. *Indicative screenshots of the Manufacturing automation-Robotics arms in manufacturing resource (IO1)*

Dissemination Activities

The partnership delivers tools and materials for the dissemination of project activities and outcomes in order to achieve the following:

- inform, promote, and build a solid case for the uptake of outputs by sectoral stakeholders.

- stimulate the cross-sectoral adaptation of outputs and/or the development of corresponding materials in the field of training and education.

The "21st Century students" project includes the following dissemination and project visibility activities:

- 6 Multiplier Events attended by a minimum of 160 target group representatives attending Events.
- 3 email campaigns with 500 recipients addressed to target groups and stakeholders all across Europe, aiming to inform, motivate, and promote involvement in project activities.
- 6 press releases
- 3 Erasmus+ Guest Blogs/Case Study
- 21st Century Students Twitter Page
- 100 Partner website/social media update
- Attendance at 80 3rd partner events
- Project website to extend the reach of dissemination efforts by exploiting the appeal of new media, especially to younger individuals and those not reached by other project dissemination activities.

Innovation of the project

The partnership will develop a novel 21st Century Student 'Learner Academy' consisting of a suite of 30 bespoke 'taster' learning resources developed by digital manufacturing experts from industry and academia.

The non-formal learning resources are innovative in nature and include virtual demonstrations of DM&D technologies & equipment, industry case-studies/podcasts, project-based learning exercises, bite sized eLearning videos, interactive games. These resources will assist learners to understand the fundamental principles of Industry 4.0 through an 'experimental learning' rather than traditional "chalk-and-talk" approach. Significantly, it will bring the world of Industry 4.0 to schools with no digital manufacturing equipment or facilities.

The '21st Century Students' project is driven by non-formal learning approaches and exposing both school students and their educators to non-traditional forms of learning and learning environments. The project will place a premium on motivating students to become 'creators' and 'innovators' through exposure to state-of-the-art digital manufacturing facilities and expertise available across the partnership. The project relinquishes the classical approach that considers the educator as the only source of information and the classroom as the only place where knowledge can be disseminated. The '21st Century Students' project will design expert led pedagogical materials created by leading industry experts and academics in the Digital Manufacturing for the benefit of the school's sector. Traditionally, schools have minimal engagement with Industry and this project will open up that opportunity for the benefit of driving curriculum and pedagogical innovations in favour or STEM. School educators and learners from across 6 EU Countries will have the opportunity to collaborate with Industry 4.0 experts and visit digital fabrication laboratories and innovation centers that they would not traditionally be exposed to. Furthermore, the partnership in itself is an innovative feature of this application as it forms an entirely new cross-sectoral relationship, bringing both experienced and non-experienced Erasmus+ partners together.

Conclusions/Impact on Education and Society

The '21st Century project' partners will focus on including students & educators with fewer opportunities during the pilot activities and through the multiplier events. It is anticipated that students and educators with cultural differences, economic, geographical obstacles and educational difficulties will be involved in the project's pilots and events.

Participants within the partners regions are facing the following situations:

- Cultural Differences: immigrants or refugees, people belonging to a national or ethnic minority, people with linguistic adaptation and cultural inclusion problems.
- Geographical Challenges: people from remote or rural areas, people from less serviced areas (limited public transport, poor facilities, villages with poor IT infrastructure/broadband)
- Educational Difficulties: people with learning difficulties/or disability, people with poor school performance
- Economic Challenges: People from economically deprived communities/ families

The partners will take appropriate measures to avoid exclusion of specific target groups and to promote access to formal and non-formal education, active citizenship, empowerment, and inclusion in society. The '21st Century project' project aims to empower and involving directly marginalized learners in its delivery while at the same time increasing the capacity of the partners to engage with the marginalized population.

Support activities will include the following supplementary activities:

- Virtual Connectivity: The 'Learning Lab' will include remote features to virtually connect schools with the project consortium expert, This will ensure schools with a lack of resources, limited or no access to facilities or face geographical barriers still can foster deeper and more diverse partnerships to drive curriculum and pedagogical innovations in favour or STEM.
- Resource Variation: The pedagogical resources within the 'Learning Academy' will be suitability designed for schools who have limited or no access to digital manufacturing facilities through the inclusion of

several 'low-resource high impact' resources (e.g., virtual equipment demonstrations, industry case studies / podcasts).

- Linguistic Support: Prior to the delivery of the 'experience days', the partners will engage with teachers/trainers to assess if a student who is participating in the pilot may have difficulty understanding the language of delivery. If required a translator or additional support staff will be used to ensure that the learner can fully participate in the pilot. Further, the translation of intellectual outputs will ensure that teachers / students face no linguistic barriers when implementing the resources.
- Accessibility: A number of pilot and dissemination events will be held throughout the project across the partners digital manufacturing labs & innovation centers. Partners will undertake prior risk assessments to ensure those with a disability or other health conditions can fully participate in the planned activities. Reasonable adjustments to these environments will be made if necessary such as adapting the layout of the room or equipment.

Through the creation and exploitation of our expert-led pedagogical resources, thousands of learners across Europe will be exposed to the latest Digital Manufacturing technologies, processes and learning resources to ensure they are 'skilling today for tomorrow'. In the longer term this is expected to have a positive impact on addressing embedded STEM challenges & enhancing the competitiveness of the manufacturing sector to cope with future industrial revolutions. Teachers will recognize the value of deeper and more diverse partnerships across education & industry to drive industry relevant learning experiences that create tomorrow's future-ready workforce. For all organizations working in the schools education field, there will be greater availability of innovative pedagogical materials and resources for educators to successful instill quality DM&D education through virtual means, particularly those with a lack of resources or no access to facilitates.

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