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Digital **Man**ufacturing Master Degree to set specialists for the dawn of the Industry 4.0

IO 1 – Guideline to align requirements of industry 4.0 to existent and designed digital technologies

Task 1

Evaluation the requirements of Digital Manufacturing in order to meet Industry 4.0

Task 2

Evaluation the Requirements of Digital Educational tools

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Introduction

DIGIMAN project aims at the development of an innovative master's degree in Digital Manufacturing. This Masters shall tackle the identified needs in terms of qualified personnel moving towards the 4th Industrial Revolution, Industry 4.0.

This document compiles an analysis in terms of Digital Industrial needs in the Manufacturing sector. Being so, this report is divided in several sections which in global give an overview of the digital innovations required in the Manufacturing sector that will boost technology towards the required developments in Industry 4.0.

The report is divided in 10 chapters.

On a first instance there is made a summary of Industry 4.0 meaning and objectives and its relation with Digital Manufacturing. The first chapters are foreseen as an introductory topic to ensure that the future developments of the project are aligned with the digital industrial needs.

After this technological characterization, project Partners considered that in order to achieve DIGIMAN main objective of tackling the skills needs in terms of Digital Manufacturing it would be necessary to start these developments by evaluating the training offer for this specific area. Being so, several Masters and post graduations were evaluated in Consortium Countries (RO, HU, DE, PT, BE, ES).

Furthermore, this report also includes a brief overview of the necessities in terms of Digital Manufacturing Technologies needs currently being addressed in industry and a forecast of the industrial needs in the future.

After the evaluation of the state of art of Digital Manufacturing Industry, there is a chapter dedicated to the requirements students must achieve by completing DIGIMAN MSc. This chapter briefly summarizes the afore mentioned needs in order to conclude in a summarized way the students' requirement.

Finally, by the end of this report the Digital Educational tools available in the market are evaluated and grouped by Augmented Reality tools, Virtual Reality tools, Robotic tools and General Educational tools. This will allow to further decide on the required Digital Tools for DIGIMAN master.7

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In the end of the report the results are summarized and concrete paths for the next steps in the project are set.

Industry 4.0 and Digital Manufacturing

Introduction to industry 4.0

The term Industry 4.0 actually comes from a project funded by the German government [1], which is said to be first made public during the 2011 Hannover Fair [2].

The term was received with enthusiasm by the worldwide industry [3] and overlaps in part with other paradigms like Industrial Internet of Things (IIoT) [4] and with other initiatives such as Made in China 2025 [5].

In addition, Industry 4.0 is directly related to the deployment of **smart factories** [6], which are conceived to manage more efficiently their resources and to incorporate enough flexibility to adapt to the production needs. Such a necessity for flexibility is associated with the fact that clients are increasingly demanding product customization [7], what impacts development and manufacturing at different stages (e.g., design, ordering, development, production, sale, after-sale or recycling).

The result in the industry has been a **new organizational model** and a disruptive change in the industry that some call the "**fourth industrial revolution**".

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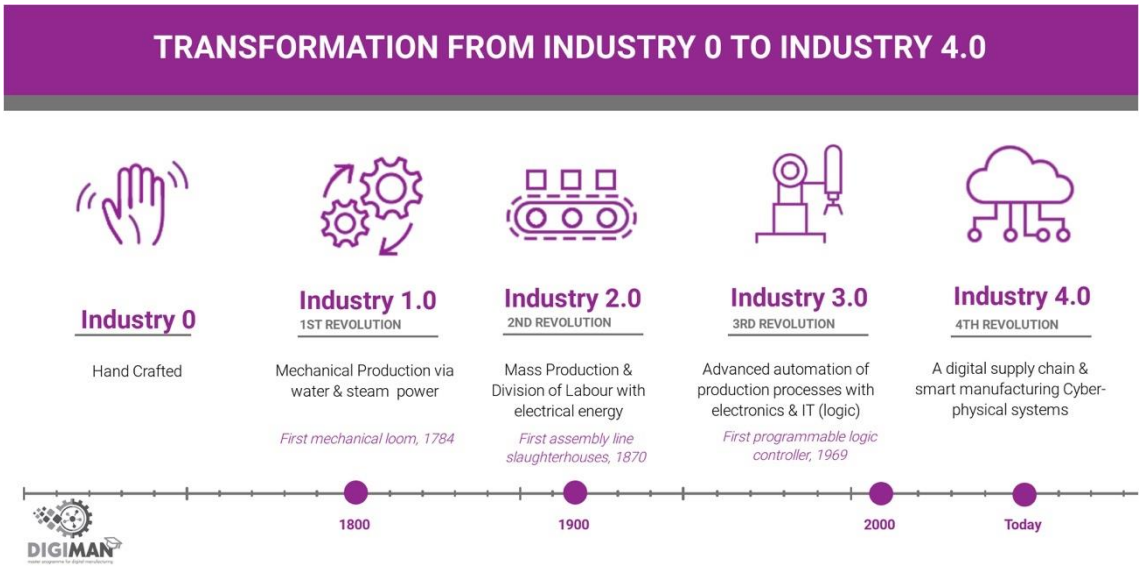


Figure 1. Transformation from industry 0 to industry 4.0.

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Design Principles & Scenarios

Accordingly, scholars such as Gilchrist [8], Liao et al. [9], Santos et al. [10], Ustundag and Cevikcan [11], and Vogel-Heuser and Hess [12], believe that Industry 4.0 can be defined based on its design principles and technology trends.

There are **four design principles** in Industry 4.0 that support companies in identifying and implementing Industry 4.0 scenarios. They include [13]:

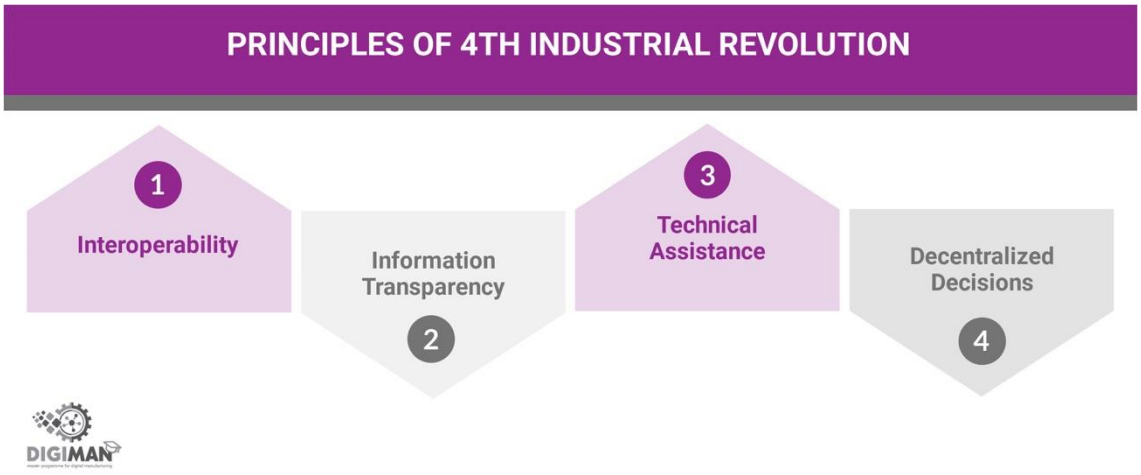


Figure 2. Principles of fourth industrial revolution.

1. Interoperability: The ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT) or the Internet of People (IoP). Adding IoT will further automate the process to a significant extent.

2. Information transparency: The ability of information systems to create a virtual copy of the physical world by enriching digital plant models with sensor data. This requires the aggregation of raw sensor data to higher-value context information.

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3. Technical assistance: The ability of assistance systems to support humans by aggregating and visualizing information comprehensibly for making informed decisions and solving urgent problems on short notice. Plus, the ability of cyber physical systems to physically support humans by conducting a range of tasks that are unpleasant, too exhausting, or unsafe for their human co-workers.

4. Decentralized decisions: The ability of cyber physical systems to make decisions on their own and to perform their tasks as autonomously as possible. Only in the case of exceptions, interferences, or conflicting goals, are tasks delegated to a higher level.

Main Industry 4.0 Technologies

The implementation of the Industry 4.0 principles requires the integration of at least ten types of technologies described below and illustrated in Figure 3.

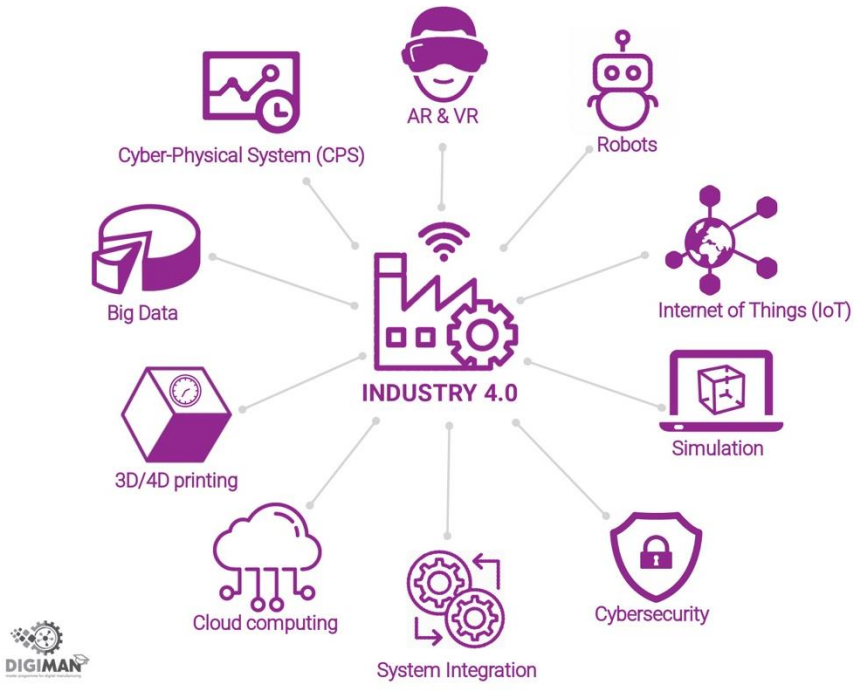


Figure 3. Industry 4.0 Technologies.

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1. IoT

The term IoT refers to the use of Internet of Things technologies [14]– [15] in industrial environments. Therefore, it implies the massive deployment of industrial sensors, actuators and machines with remote sensing/actuation capabilities [16]– [17].

2. CPS

A Cyber Physical System or CPS can be defined as a system with processing, storing and communication capabilities that is able to control one or more physical processes. Such systems are usually interconnected with each other or through the Internet, what decentralizes data analysis and decision-making, enabling real-time responses [18]– [19].

3. Vertical and horizontal integration system

Horizontal and vertical integration are key for Industry 4.0 in order to automate data transmission in smart factories and to communicate with providers and clients. Therefore, software like Manufacturing Execution System (MES), Product Life-cycle Management (PLM), Enterprise Resource Planning (ERP) and IoT platforms will have to evolve to provide the required integration level [20].

4. Additive manufacturing (3D/ 4D printing)

The flexibility and customization brought by additive manufacturing are essential in the Industry 4.0 paradigm. Ideally, such characteristics should be provided without raising the price of the product and should not depend on the fact that the manufactured products are identical or different. More-over, additive manufacturing will make it easier to produce low-volume batches or prototypes, which, traditionally, have been expensive. Furthermore, decentralized additive manufacturing will reduce delivering times and will enable stock management optimization [20].

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5. Big Data and Data Analytics

This is extremely large data sets analysed to reveal patterns, trends, and associations, especially relating to human behaviour and interactions.

Big Data solutions change the established business models. Today not a single intelligent solution is possible without big data [21].

6. Cybersecurity

Connectivity is essential in Industry 4.0 applications, so it is required to protect industrial critical systems and manufacturing lines from cyber-attacks, whose impact has grown remarkably in the last years [22]. Therefore, it is key to provide secure and reliable communications, authentication systems and preserve data privacy in order to avoid attacks [23]– [24].

7. Cloud and edge computing

Many companies are already deploying applications on cloud computing systems, which are fostered by Industry 4.0 in part because they ease the collaboration with third parties. Nonetheless, note that traditional cloud-based systems have certain limitations [25], as the cloud is considered a point of failure: when maintenance, software problems or attacks occur, the whole system is blocked. Moreover, it is important to emphasize that, if the amount of IoT-connected devices keeps on growing at the same rate [26], the amount of communications to be handled will increase remarkably and, therefore, the cloud may constitute a bottleneck. Due to this issue, other alternative architectures based on edge computing have been proposed, like fog computing [27] or cloudlets [28], which enable offloading part of the processing from the cloud to the edge of the network, also decreasing latency response [29], [30].

8. Simulation software

The collected information can be processed in order to model the behaviour of machines, products and workers of certain industrial processes. Such an information can be fed into

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software that enables simulating future scenarios in order to determine necessities, predict problems, reduce configuration costs and improve quality. This kind of software is also related to the concept of Digital Twin [31], which represents the actual situation on a real-world factory through visual interfaces, what allows for remote monitoring and supervising operations.

9. Autonomous robots and vehicles

The next generation of robots that will be used in Industry 4.0 applications includes Cobots [32], industrial robots [33] and Autonomous Ground Vehicles (AGVs) [34], which can be interconnected and work in a collaborative way. Cobots help human operators in different tasks, while robots can perform certain specific tasks, like searching items or transporting tools in an autonomous way. Regarding AGVs, they are mainly targeted at logistics and transport in industrial environments, existing AGVs for mining [35], material handling [36] or for automating industrial vehicles [37].

10. Augmented and Virtual Reality

Augmented Reality or AR is a technology that makes use of an electronic device to view, directly or indirectly, a real-world physical environment that is combined with virtual elements. In the case of Virtual Reality (VR), both the environment and the elements are virtual. AR and VR have progressed a great deal in the last years and they have proven to be useful in different stages of an industrial process, like design [38], [39], manufacturing [40], [41] or maintenance [42], [43]. In fact, it has been demonstrated that technologies like AR can help operators to avoid mistakes in assembly tasks and increase productivity [44].

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Introduction on Digital Manufacturing

Recently, emerging technologies have game-changing impacts on manufacturing models, approaches, concepts, and even businesses.

As stated above, the term Industry 4.0 incorporates emerging technical advancement to improve industry so as to deal with some global challenges that is oriented towards digital and virtual technologies and it is driven by real-time data interchange and flexible manufacturing, enabling customized production [45–46].

Being **Digital Manufacturing** (DM) under the umbrella of Industry 4.0 technologies, Hartmann et al. [47] points out that industry leaders agree that Digital Manufacturing technologies will transform all aspects in the manufacturing systems of value chains.

Digital Manufacturing technology has evolved from **Computer Integrated Manufacturing** (CIM), which was **developed in the 1980s** when the reduced cost of computing meant computers could be used extensively for machine and automation control, planning and scheduling. CIM has worked as a connection between manufacturing, systematic science, and other related issues, and these merge into the manufacturing industry [48,49].

Manufacturing becoming increasingly multidisciplinary was perhaps inevitable. From the combination of organizational sciences, such as Lean Manufacturing, Total Quality Management - TQM, and Concurrent Engineering; with engineering science of CIM emerged the concept of Digital Manufacturing that highlighted the need for more collaborative product and process design [49].

There are multiple **definitions** of Digital Manufacturing, but all converge to the central idea of manufacturing improvement using technology integration. There is also a common view of Digital Manufacturing as being synonymous to '**digital factory**' [50].

According to Professors McFarlane & Brintrup from Cambridge University, the broadest possible definition about Digital Manufacturing could be [51]:

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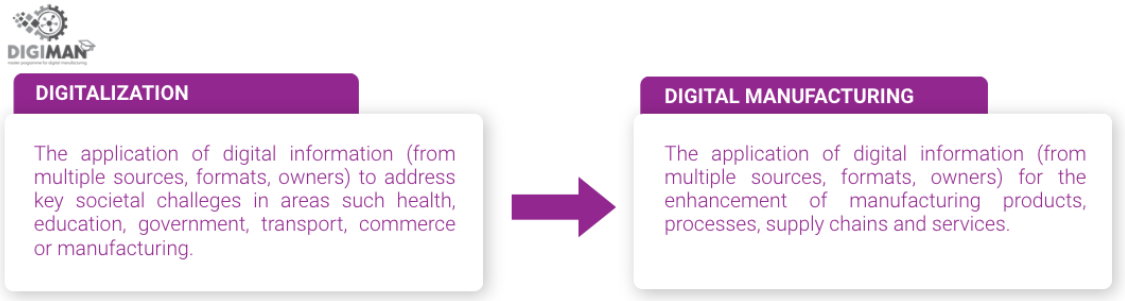


Figure 4. Definition about Digital Manufacturing.

The same authors referenced above [51] affirm that Digital technologies are not a new term since they have been used in manufacturing for more than 30 years:

1990s The application of digital information for the enhancement of manufacturing processes.

2000s The application of digital information for the enhancement of manufacturing processes and supply chains.

2010s The application of digital information (from multiple sources, formats, owners) for the enhancement of manufacturing processes, supply chains, products and services.

What is new is the scope of the application and the recent evolution of key technologies such as personal mobile computing, cloud-based computing, ubiquitous internet and others [51].

Considering all the exposed definitions about Digital Manufacturing, it can be deduced that **Digital Manufacturing is an integrated approach to manufacturing that is centred around a computer system**.

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A machine is able to read a Computer Aided Design (CAD) file in order to deliver it in a few hours. Within the same process, it is possible to prototype, produce and fabricate moulds to aid production. The rapidity of the process allows an iterative production.

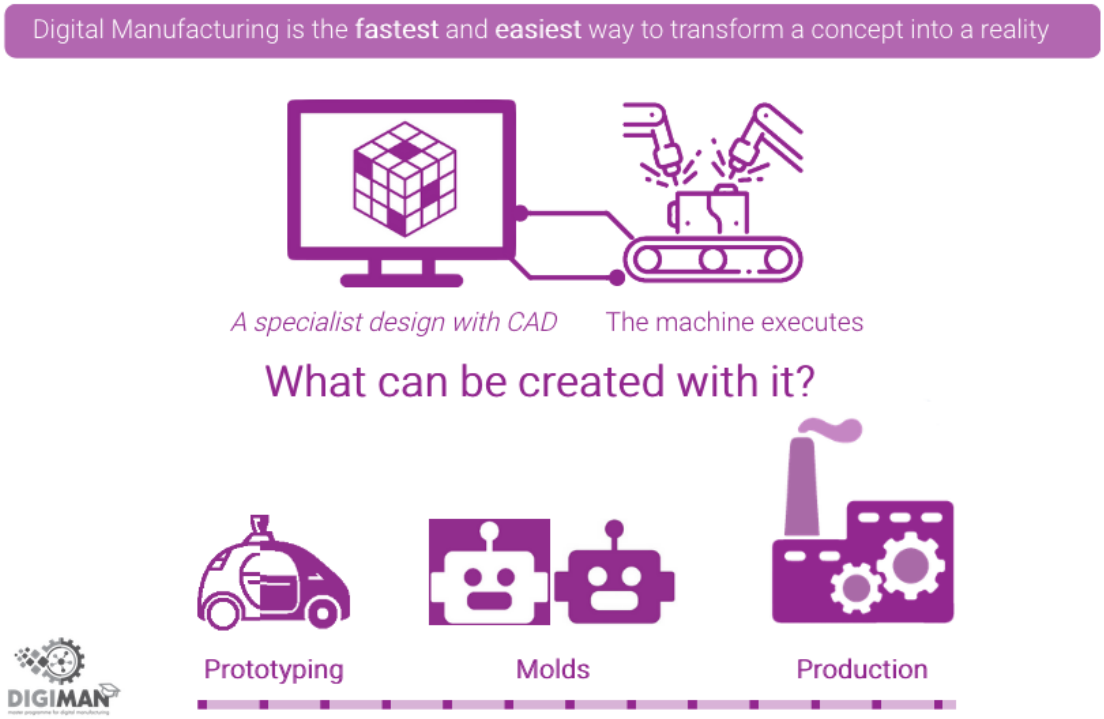


Figure 5. Possibilities of Digital Manufacturing.

Digital Manufacturing technologies:

Digital Manufacturing belongs to a much larger trend known as the **Fourth Industrial revolution** (described in previous section), which combines CAD design, Digital Manufacturing, robotics, sensors & data and analytics to **redefine industrial production.**

Digital Manufacturing technologies include [52]:

Additive manufacturing, often called 3D printing, consists in fabricating an object one layer after the other. It covers various technologies (SLS, Polyjet, FDM, DMLS…)

Laser cutting is a digital subtractive fabrication technique. It consists in cutting or engraving a material (like metal, wood, cardboard…) by means of laser.

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Water jet cutting is a manufacturing process that cuts material using a very high-pressure jet of water that can be up to 6150 bars.

Plasma cutting is a technology used to cut through conductive materials. It uses gas and electricity to cut through a different number of components, whether it is brass, copper, aluminium or steel.

CNC (Computer Numerical Control) is a subtractive manufacturing process where a computer controls the cutting and shaping of parts (typically, metal).

Digital Manufacturing helps companies go faster, invest less money and reduce the cost of trial and error [53].

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Existing Masters in Digital Manufacturing

A desk research was conducted in order to assess the contents of Digital Manufacturing and related Masters in German, Portugal, Romania, Hungary, Spain and Belgium. The following table illustrates the Masters considered relevant in each of consortium Countries: (To have a full overview of the information collected please check annex 1)

This desk research will help future developments of DIGIMAN project since it will help in the definition of the content to be held at DIGIMAN Digital Manufacturing master course, through the evaluation of similar courses in Consortium Countries.

Country: Germany						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Digital Industrial Management and Engineering (M.Sc.)	Reutlingen University	DE & EN	Presence based	120	4 sem.
2	Master in Production & Operations Management (POM) (M.Sc.)	Karlsruher Institute of Technology	EN	Presence based	90	3 sem.
3	Smart Factory - Industrie 4.0 (M.Eng.)	Esslingen University of Applied Sciences	DE	Presence based	95	3 sem.
4	Mechatronic and cyber-physical systems (M.Eng.)	Deggendorf Institute of Technology	EN	Presence based	90	3 sem.
5	Precision Manufacturing and Management (M.Sc.)	Furtwangen University	DE & EN	Presence based	90	3 sem.
6	International Production Engineering and Management (IPEM) (M.Sc.)	University of Siegen	DE	Presence based	120	4 sem.
7	Advanced Manufacturing (M.Sc.)	Chemnitz University of Technology	DE	Presence based	120	4 sem.

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Country: Portugal						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Specialization Course in Digital Manufacturing	Universidade Nova	EN	Presence based	16	20 weeks 20h/w
2	Master in Engineering for Direct Manufacturing	Politécnico de Leiria	EN	Presence based	120	4 sem.
Country: Romania						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Virtual engineering and competitive manufacturing	Technical University of Cluj Napoca	EN	Presence based	120	4 sem.
2	Conception intégrée des systèmes technologiques	University POLITEHNICA of Bucharest	FR	Presence based	120	4 sem.
2	Innovative Manufacturing Engineering	Transilvania University of Brasov	RO	Presence based	120	4 sem.
Country: Hungary						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Design and Technology Cyber-Physical manufacturing systems	Budapest University of Technology and Economics	HU/EN	Presence based	120	4 sem.
2	Mechatronic Engineering MSc	Óbuda University	HU	Presence based	120	4 sem.
3	MSc in Computer Science and Engineering	Óbuda University	HU	Presence based	120	4 sem.
4	Design and Technology Cyber-Physical manufacturing systems	Budapest University of Technology and Economics	HU / EN	Presence based	120	4 sem.

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5	Mechanical Engineer MSc	John von Neumann University	HU	Presence based	120	4 sem.
6	Mechanical Engineer MSc	Szent István University	HU	Presence based	120	4 sem.
7	Mechatronical Engineering MSc	University of Győ	HU	Blended	120	4 sem.
Country: Spain						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Industry 4.0 and Digital Transformation	UADIN Business School & UDIMA Universidad a Distancia de Madrid	ES	Online presence	60	2 sem
2	Industry 4.0: Digital Industrial Transformation	International University of Valencia	ES	Online presence	60	2 sem
3	Digital Manufacturing	University of the Basque Country	ES/EN	Presence based	90	3 sem
4	Industry 4.0	International university of La Rioja (UNIR)	ES	Online presence	60	2 sem
5	Industry 4.0	Polytechnic University of Catalonia	ES	Blended learning	60	2 sem
6	Industry 4.0	Open University of Catalonia & ESUPT	ES	Online presence	60	2 sem
7	Connected Industry 4.0	University Carlos III	EN	Presence based	60	2 sem

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8	Industry 4.0	SEAS – Open Higher Education – San Jorge University	ES	Online presence	60	2 sem
9	Industry 4.0	University of Alcalá	ES	Blended learning	60	2 sem
10	Industry 4.0	Catholic University of Alava	ES	Online presence	60	2 sem
11	Technologies Applied To Industry 4.0	University of Salamanca & IBM	ES	Online presence / Blended Learning	60	2 sem
12	Industry 4.0	University of Córdoba	ES	Presence based	60	2 sem
13	Smart Industry	University of Comillas	EN	Presence based	60	2 sem
14	Smart Industry	University of Jaen	ES	Presence based	60	2 sem
Country: Belgium						
Nº	**Master name**	**Institution**	**Language**	**Modality**	**ECTS**	**Duration**
1	Master of Science in Electromechanical Engineering (Control Engineering and Automation)	Ghent University - Faculty of Engineering and Architecture	EN	Presence based	60	4 sem.
2	Master of Electromechanical Engineering Technology (Leuven)	KU Leuven	EN	Presence based	60	2 sem.
3	Master of Science in Electromechanical Engineering	Vrije Universiteit Brussel	EN	Presence based	120	4 sem.

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Due to the amount of information collected there was the need to summarize the major outputs from the courses identified previously. The Knowledge identified in each Master was separated into 6 distinct groups: Industrial Production Technologies, Industrial Control Management and Operations, Digital, Technological Field, Communication and Other. On the upcoming phases of the project these groups will be considered, and partners will use the information identified here to specify the Knowledge areas that compose DIGIMAN MSc.

The following knowledge fields were highlighted from the selected Master programmes:

(To have a full overview of the conducted desk research please check annex 1)

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Industrial Production Technologies

- Digital Industrial Management
- Industry 4.0 concepts
- Industrial Engineering
- Industrial Digitization
- Additive Manufacturing processes
- Production management
- Production Technologies
- Manufacturing methods
- Digital Fabrication
- Direct Digital Manufacturing processes
- Automation and Robotics
- CNC programming
- Computer aided manufacturing
- Intelligent Manufacturing
- Flexible Manufacturing
- Rapid prototyping
- Mould production and casting
- Virtual Manufacturing
- Robotics

Industrial Control Management and Operations

- Business management and models
- Planning, developing and monitoring
- Supplying, procuring and distributing.
- Logistics
- Motion control systems
- Quality Assurance
- Quality Management

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- MOM (Manufacturing Operation Management)
- Industrial Strategy
- Project Management
- Life cycle management
- Stock Management
- Production planning and management (JIT, MRP)
- Strategy and Management for Digital Transformation
- Problem solving applied to industrial challenges
- Optimize the efficiency of value-added processes

Digital

- Interface between industry and technology
- Digitization processes
- Digital Transformation
- Computer aided design
- Virtual engineering methods
- Software-based control and automatization systems
- Cooperative and autonomous systems
- Advanced software for simulation and management
- Software engineering
- Innovative human-machine interfaces
- Cybersecurity
- Cloud Computing & Big Data
- IoT (Internet of Things)
- Artificial Vision
- Virtual Reality
- Augmented Reality
- Machine Learning
- Artificial Intelligence

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- Blockchain
- RPA (Robotic Process Automation)
- Data Mining
- Data Analysis
- Models for advanced data processing
- Intelligent systems

Technological

- 3D scanning
- Design
- Simulation
- Modelling
- Mechanic Engineering
- Mechatronic Engineering
- Electromechanical Engineering
- Electronics Engineering
- Materials characterization and application
- Mathematics

Communication

- Cultural context and its complexities when making decisions in a global business environment
- Information technology
- Intercultural and linguistic competences
- Information and communication technologies

Other

- Research specific methods and tools
- Team Working in Industrial context
- Recycling

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- Environmental protection
- Legal and regulatory framework of industrial activity

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Inventory of existing Digital Technologies in industrial sector

As explained previously, Digital Manufacturing is foreseen to have a large impact on several industries all across Europe and the world. At this point of the report will focus on some of the main technologies identified in Digital Manufacturing. Furthermore, DIGIMAN project will aim to address all the technologies mentioned here in the Master course developed.

The Technologies addressed are as follows:

Additive Manufacturing – Additive Manufacturing or commonly known as 3D printing is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. [54]

Additive Manufacturing (AM) is quite an innovative technology in the fields of Digital Manufacturing. Some studies consider AM as one of the key technologies in the digital industrialization Era. Its unique features such as the fact that AM allows manufacturers to produce highly specialized parts and the advanced software usage allows manufacturers to place printing/building orders online promoting in this way one of Industry 4.0 objectives of assigning a part for production from a distance.

CNC – Computer Numerical Control (CNC) is a method for automating control of machine tools through the use of software embedded in a microcomputer attached to the tool. It is commonly used in manufacturing for machining metal and plastic parts. [55]

CNC is commonly used in Digital Manufacturing industry since it allows connection and control between different industrial processes. Consortium Partners considered this technology as relevant for the content of the master's course due to its high potential and impact on industry.

Laser Cutting – Laser Cutting Laser cutting is a precise method of cutting a design from a given material using a CAD file to guide it. It involves firing a laser which cuts by melting, burning or vaporizing the material. [56]

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Laser Cutting is one of the main technologies in this new digital Era. Manufacturing of parts is becoming more complex allowing built of more complex parts, and due to technologies, such as Laser Cutting Digital Manufacturing is pushing the manufacturing sectors towards efficiency and competitiveness.

Plasma Cutting – Plasma Cutting is a melting process in which a jet of ionised gas at temperatures above 20,000°C is used to melt and expel material from the cut. During the process, an electric arc is struck between an electrode (cathode) and the workpiece (anode). The electrode is recessed in a water- or air-cooled gas nozzle which constricts the arc causing the narrow, high temperature, high velocity plasma jet to form. [57]

This technology had an increase of usage in the last couple of years and is being addressed as one of the relevant technologies in the Digital Manufacturing field.

Water Jet Cutting – Cutting with a water jet is a method of engineering for cutting objects using the energy from high speed, high density, ultra-high-pressure water. [58]

This technology is being used in some of industrial companies working with Digital Manufacturing Technologies.

After this characterization of the main processes in this new digital Era, DIGIMAN Consortium decided to validate its research amongst industrial experts in order to ascertain that the results found were applicable through the Consortium Network.

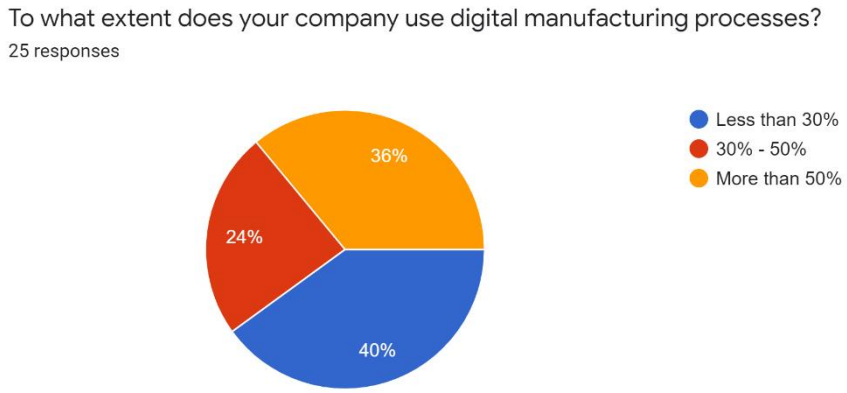
Three main areas of concern were addressed in this Survey. The first focused on understanding to what extent was Digital Manufacturing used in Partners Network. The second was related to the applicability of the afore mentioned Digital Technologies in the same network. Finally, the third topic was related to the Digital Manufacturing competences and skills needed amongst project stakeholders.

The results from this survey will contribute to further developments in DIGIMAN project while identifying a clear pathway towards a student Curriculum that fully addresses industry needs.

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The survey was applied to 24 Industrial Companies and Clusters from DIGIMAN network. The Companies are representatives of several sectors, and any sector highlights from the others. This is aligned with DIGIMAN objective of building an innovative Curriculum where the student can scale through several Digital Manufacturing industries after completion of the course, not being restrained to one specific industry.

1st Question:

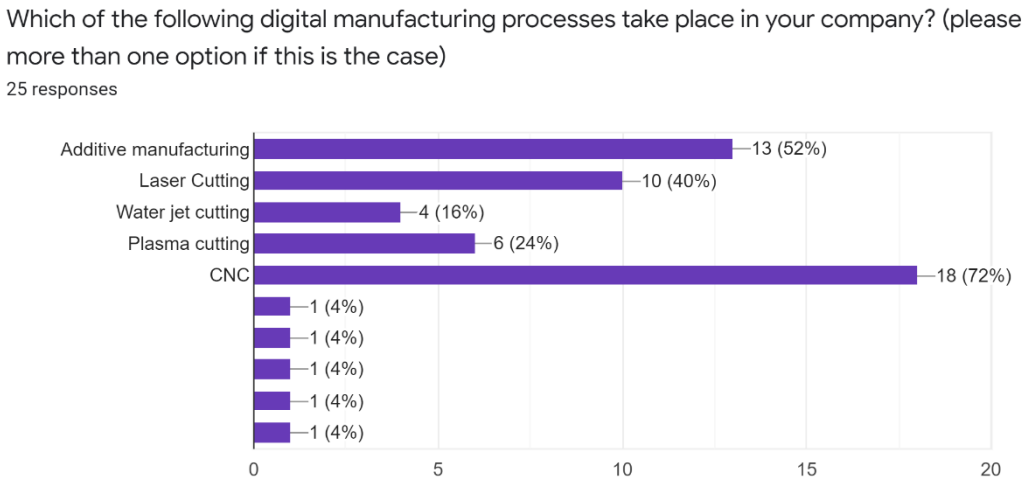


As a result, most of the participants answered quite positive to the use of Digital Manufacturing technologies in their own Companies. The results are divided mostly between More than 50% and less than 30% which made DIGIMAN Partners predict that once the Company starts using Digital Manufacturing processes there is a narrow window between using few and increase the use to more than half of the production.

This means that Digital Manufacturing is rapidly increasing (as previously presented) and Industrial Companies and Clusters can easily adapt new manufacturing processes in their production.

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Question 2:

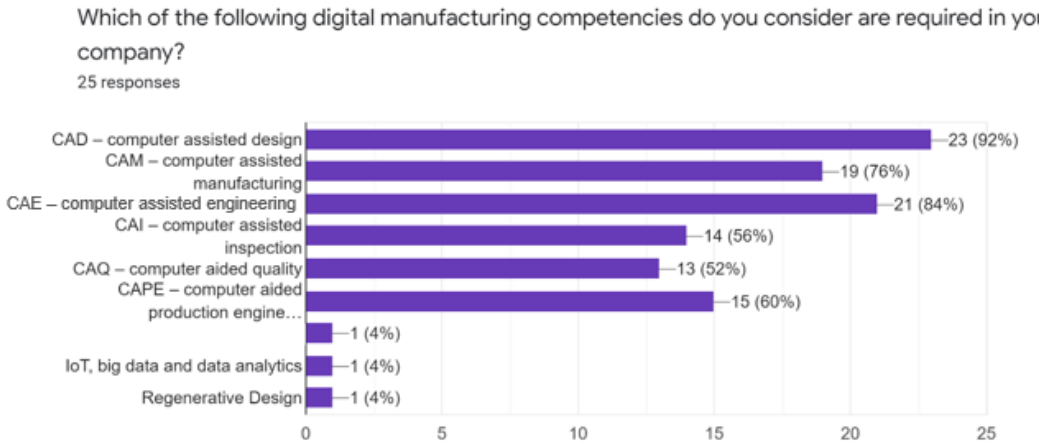


This question aimed at validation of Partners research on the main Digital Manufacturing Technologies. From the sample used most of the participants answered that CNC is used in their companies followed by still significant Additive Manufacturing. Then with less significant results come the Subtractive Manufacturing Technologies such as Laser, Plasma and Water Jet cutting. Other processes were identified in the areas of robotics and self-development manufacturing software.

These results boost DIGIMAN project to reach its objectives since it has been validated the industrial needs in terms of the use of Digital Manufacturing Technologies.

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Question 3:



The final question of the survey conducted aimed at assessing the workers needs in terms of competencies required in the field of Digital Manufacturing. It can be understood that most Participants answered positive to most of the competencies identified, which allows to conclude that a Digital Manufacturing MSc student must have all the selected competencies after completion of the course when entering the labour market. Furthermore, an analysis of the results concludes that CAD (computer assisted design) and CAE (computer assisted engineering) are the two most relevant competences. Nevertheless, the results are quite similar for all competencies which sustains the hypothesis that all competencies are necessary in the Digital Manufacturing industry.

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Student Profile Requirements

Each day, driven by modern technology and digitalisation, businesses and workers are challenged to be even more innovative as it stands for progress and growth. The ever-increasing demand for digital skills in combination with solid knowledge of other technical competences in manufacturing engineering leads towards a proper response from the higher education field in terms of study programmes.

Trying to determine how the higher education institutes deliver education & training that shall meet the rapidly emerging demands in terms of Digital Manufacturing is perhaps the most challenging questions both in terms of the existing workforce as well as in the education and training systems as a whole.

According to the Council of European Employers of the Metal Engineering and Technology-Based Industries (CEEMET) the education and training systems in Europe are hardly catching up with the pace of technological change and need to provide more flexible education programmes and to integrate the learning of digital technology and skills across all curricula [59].

Digital Manufacturing technologies bring vast changes in skills and competence requirements as well as in teaching and learning. Today across the EU, there aren't enough skilled workers to fill all of the skilled manufacturing jobs available. The skills gap, and in particular the mismatch between the skills needed by the manufacturing industry and the skills available, is a major cause of reduced competitiveness for companies.

The competence demand for a digital industry must be addressed by focusing on Science, Technology, Engineering & Mathematics – STEM. The demand for STEM competence now extends to areas such as advanced manufacturing, utilities, transportation, mining, and other technology-driven industries. Moreover, as Industrial Revolution 4.0 gains momentum and influences every aspect of our everyday lives, the boundaries between STEM disciplines and also between STEM and non-STEM fields, are becoming more and more blurred [60]. In the same time experts in Digital Manufacturing industries are

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more and more required by different companies and institutions acting in automotive industry, railway, shipbuilding, aircraft industry, research and innovation, services just to mention few domains. The acknowledged objective of STEM education is to develop well-informed and highly competent citizens in the age of the 4th Industrial Revolution.

The envisaged Master Programme framework developed in the DIGIMAN project comes to fill the gap between the requirements of the industrial sector in terms of Digital Manufacturing competencies and the higher education institutes curricula. Therefore, new developed MSc programme is intended to educate engineers in the field of Digital Manufacturing.

In order to enrol in the Digital Manufacturing MSc. Programme the candidates must hold a Bachelor's degree in one of the following domains:

- Industrial Engineering,
- Mechanical Engineering,
- Electrical Engineering
- Electromechanical Engineering
- Materials Science,
- Engineering and Management
- Logistics
- Computer Science

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Existing Digital Tools

At this point of the report will be evaluated the manufacturing needs in terms of digital tools as well as a summary of the available digital tools in the market. This evaluation of available digital tools is separated into distinct areas, namely Augmented Reality, Robotics, Virtual Reality and General Digital Educational Tools.

Hereinafter, will be summarized the educational tools for each of the topics mentioned above.

Augmented Reality in the Educational Process

When the term Augmented Reality (AR) was coined back **in 1990**, some of the first commercial uses were, of course, in television and military. However, since then the AR technology has significantly evolved and today, we see Augmented Reality applications in every industry with reported benefits from its users, including education [61].

Learning benefits and limitations of Augmented Reality

Augmented Reality applications [62] in education provide new ways of teaching and learning, bridging the gap between the virtual and real world. The benefits of AR in education are increasingly being recognized by researchers on the topic.

Researchers have reported [63] on the positive impact that Augmented Reality experiences have on learners as compared to non-AR ones:

- Increased content understanding
- **Learning spatial structure and function:** Augmented reality can be used for improving spatial abilities of engineering students. AR can provide 3D virtual models that help students to perform visualization tasks to promote the development of their spatial ability during a study [64].

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- Learning language associations
- Long-term memory retention
- Improved physical task performance
- Improved collaboration
- Increased student motivation

The researchers also reported just a few learning detriments from Augmented Reality, all of which can successfully be avoided:

- Attention tunnelling
- Usability difficulties
- Ineffective classroom integration
- Learner differences

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Augmented Reality educational tools

Augmented Reality tools let students not only engage with the technology but also it gives them the possibility to create their own content.

This is paramount in order to promote 21st-century skills such as creativity, problem-solving, critical thinking, analysis, coding, and iterative testing, the process of basing **tests on insights** gathered from previous tests in order to make changes gradually and which are evidence-based.

For the functioning of AR app, it is enough to have a **standard camera** and a **mobile device graphics chip**. Also, it is possible to use specialized hardware and software. Most of them are a headset that extends the capabilities of a smartphone, such as **Google Glass**. However, there are also devices that can function independently, for example, Microsoft **HoloLens**. By adding a mobile phone to the training system, the work process becomes

more visual, interactive and understandable [65].

A search of the internet reveals a variety of web-based AR tools and apps for almost any subject[1].

Pioneers and platforms that have contributed greatly to the creation of augmented reality apps are summarized chronologically here in the following short list [66]:

- **Metaio** – Metaio was established in Munich, Germany in 2003 and was the first to provide a software development kit (SDK) for programming PC, web, mobile and custom offline augmented reality apps. Metaio founded Junaio, a free AR mobile browser that was available for Android and iOS devices. That company was acquired by Apple in May of 2015.
- **Vuforia** – This software development kit (SDK) for mobile devices can be used to create augmented reality apps. It uses computer vision technology to detect and track 3D objects in real time. With this feature, developers are able to position and align virtual objects, such as 3D models and other media, in relation to real-world objects when viewed through the camera of a mobile device. The virtual object

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tracks the position and orientation of the image in real time so that the viewer's perspective of the object matches the perspective of the target. It appears as if the virtual object is part of the real world.

- **Wikitude** – (World Browser) is an augmented reality app for mobile devices developed by the Austrian company Wikitude (Mobilizy before the end of May, 2011) and released as freeware in October 2008. Wikitude is also the first mobile app based on a location-oriented approach to augmented reality.
- **Tango** – was a project by Google that was able to bring augmented reality to mobile phones and was the first project to use depth sensors – as on the HoloLens or Magic Leap One. This allowed a very high level of accuracy to be achieved. However, Tango requires special sensors that were only installed on a few devices and Apple captured market share with ARKit, so Google had to find a solution suitable for the broad public. As a result, Tango was discontinued in 2014 and replaced by ARCore, although from today's point of view it still provides the best mobile AR experience.
- **ARCore** – Google introduced a new AR system called ARCore in response to Apple's ARKit at the end of August 2018. It also includes the essential functions for developing AR experiences.
- **ARKit** – is Apple's augmented reality development platform for newer iOS mobile devices, includes the essential AR function, and is available free of charge, unlike Vuforia and Wikitude. It makes augmented reality suitable for widespread use by enabling broad distribution allowing developers to use it for free. The created AR scenes can be made persistent and can also be seen by other people who visit the place later.
- **VisionLib** – An SDK developed at the Fraunhofer Institute that enables very good 3D object recognition.

Today Vuforia, ARKit, ARCore, VisionLib and Wikitude are the most used SDKs for AR experiences on mobile phones. Many basic functions are often identical, but they

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differ in reliability, accuracy, and stability in the more difficult areas, such as object recognition and image recognition.

In addition to these specific tools for creating AR, it is necessary to mention **Unity,** a cross-platform game engine, launched in 2005, aiming to "democratize" game development by making it accessible to more developers. As of 2018, the engine had been extended to support more than 25 platforms. The engine can be used **to create** three-dimensional, two-dimensional, virtual reality, and **augmented reality games**, as well as **simulations** and other experiences. The engine has been adopted by industries outside video gaming, such as film, automotive, architecture, engineering and construction.

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Robotics Technologies in the Educational Process

Seymour Papert has pioneered the use of computers and robots as a way of learning. He believed on learning by making, where students were encouraged to discover and build knowledge through practical activities [67].

Robotics applications in education could also act as a supplement for Project Based Learning (PBL), which was first put forward by John **Dewey** in 1897. This student-oriented pedagogy that involves an active classroom approach encourage students to learn by doing so that they acquire real knowledge through positive exploration of challenges and problems in the learning process [68].

Educational Robotics (ER) is a multidisciplinary approach involving design, assembly and use of robots applying principles of engineering, computing, mathematics, physics, among other sciences [69].

Learning benefits and limitations of educational robotics

In the last decade, robotics has attracted a lot of researchers, teachers, and schools as a very essential learning tool to develop many skills from pre-school to high school [70].

Many researchers and studies [71] consider that application of robotics in higher education benefits both students and instructors providing them multiple advantages as:

For students

- Develops programming skills
- Develops collaboration, communication, and problem-solving
- Innovative, logical and critical thinking
- Creativity
- Group-working ability development
- Broader personal interests' cultivation
- Reducing behavioural issues

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- Supporting positive student interactions

For instructors

- Enrich teaching methods and classroom activities
- Enliven classroom atmosphere
- Explain sophisticated knowledge
- Demonstrate experimental processes
- Save instructors from repetitious demonstration
- Better optimize teaching resources

Although the benefits of using ER are evident, there are some obstacles to be overcome. Some of them are:

- Lack of teacher training
- Reluctance to use new teaching methods
- Low interest in introducing ER as a teaching tool
- Economic cost

Educational Robotics tools

ER is an effective educational tool indicated for teaching Science, Technology, Engineering and Mathematics (STEM), physics, biology and Computer Science in all levels of education [72].

It is a multidisciplinary approach involving design, assembly and use of robots applying principles of engineering, computing, mathematics, physics, among other sciences.

Usually educational robotics have different technical, structural, and functional features, but they share at least one common goal that is education. As educational tools they are made in a specific way with specific materials and level of complexity suitable for laboratory usage. They also have different built-in pedagogical solutions that direct learners to certain actions and which helps them to learn different topics. [73]

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Educational robots can be categorized as [74]:

- **Robotics kits:** are programmable construction kits that allow students to create, build, and/or program robots [75].
- **Social robots:** are based on artificial intelligence and autonomous behaviors. Social robots include Socially Interactive Robots (SIR) and Socially Assistive Robots (SAR) [76]. The key feature of social robots is that they can communicate and interact with students.
- **Toy robots:** are ready-made commercial robots for entertainment and play [77].

We are focused on educational robots that fall into the robotics kits category because they are usually used in many universities as an educational tool.

Robotics kits are very important because they enable morphological transformations as well as the possibility for extension of the hardware in order to cover various functions and applications.

Even more, they also enable functional transformations through software modifications.

- **Lego Mindstorm** [78] is a programable robotics kit, based on Lego building bricks with special robot parts. The kit includes: servo motors, sensors (ultrasonic, sound, touch, and light), wheels, gears, axes, connection and interface cables, the intelligent brick etc. All these parts are used for the construction of a robots or other automated systems. The intelligent brick is the "brain" of a Mindstorms system, that lets the constructed robot to autonomously perform different operations. LEGO Mindstorms kits are counted among the most widespread tools for teaching robotics and programming.
- **Boe-Bot** [79] is a robot kit that uses a BASIC Stamp 2 programmable microcontroller. Its name (Boe-Bot), comes from the Board of Education carrier board that is mounted on its wheeled chassis. Using this robot kit, students can build several different robots using an engineering style approach.
- **The MiniSkybot** [80] is a mobile robot aimed for educational purposes. The robot is built from 3D-printable parts, and uses a fully open-source mechanics and

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electronics parts, which can be modified and replaced according to needs. This robotic platform allows the students not only to learn robot programming, but also to modify easily the chassis and create new custom parts. It is also very cheap, since the price is almost exclusively determined by the cost of the servos, electronics and sensors.

- **VEX robotic platform** [81] is designed from the ground up to encourage students' creativity in problem solving. The kit includes microcontroller that acts as the robot "brain", allowing for both autonomous and driver control of robots. The microcontroller also includes wireless communication, enabling remote control with joysticks. The programming part can be done using the VEX coding studio, which is easy to use and easy to learn. Students can learn to program with blocks, transition to text and move into C++ as their skills advance. Users can also test their coding skills with Robot Virtual Worlds, which is a high-end virtual environment.
- **Fable** [82] is a modular construction system that can be used to create different types of robots. Students can assemble modules together in many different configurations. They can build custom robot bodies, use the inbuilt sensors and program the robot's movement. Depending on experience level, students can program using visual blocks (Blockly) or a programming language (Python). While working with Fable students are able to develop comprehensive skills in robotics, programming and innovation.
- **Alpha Bot2 robot** [83] supports Arduino, Raspberry Pi 3 Model B, and Raspberry Pi Zero W, with different adapter boards. It features rich common robot functions including line tracking, obstacle avoiding, Bluetooth/infrared/WiFi remote control, video monitoring, etc. It has a highly integrated modular design, which make it easy to assemble by a snap, no soldering, no wiring. AlphaBot2 employs a 2-layer structure to provide excellent stability and compatibility.
- **Linorobot** [84] is a suite of Open Source ROS compatible robots that aims to provide students, developers, and researchers a low-cost platform in creating new exciting applications on top of ROS (Robot Operating System). Students can use

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engineering skills to build different robots from the ground-up using easily accessible hardware.

- **Makeblock Ultimate Robot Kit** [85] is a comprehensive robot kit for building complex robots and exploring the robotic world. It contains: metal geared motors, Arduino-compatible controller, programmable RGB LED strip, different kinds of sensors, robotic gripper and other mechanical parts. The constructed robot can be controlled using a smartphone or tablet through Bluetooth connection.
- **The Speechi robotics sets** [86] are carefully thought tools, to learn coding, robotics, electronics, and how those are used in our everyday lives. The sets include: multidirectional building bricks, as well as sensors and actuators (servomotors, buzzer, etc.). Different programming interfaces and languages are used, thus allowing a smooth learning curve: icons-based interface, Scratch, Arduino (C, Java), Python, Microsoft MakeCode.
- **The BIOLOID** [87] is an educational robot kit which helps students to learn the basics of structures and principles of robot joints. The name BIOLOID comes from BioAllDroid (Bio + All + Droid = BIOLOID). The BIOLOID platform consists of components and small, modular servomechanisms (AX-12A Dynamixels), which can be used in a daisy-chained fashion to construct robots of various configurations, such as wheeled, legged, or humanoid robots. The Robot is programmed with RoboPlus - C language-based software solution.

Virtual Reality in the Educational Process

Virtual reality can be used to enhance student **learning** and engagement. **VR education** can transform the way **educational** content is delivered; it works on the premise of creating a **virtual** world — real or imagined — and allows users not only see it but also interact with it. [88]

Virtual reality technology has the potential to greatly enhance collaboration between teachers and students, both in distance learning and classroom-based teaching. Research

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shows that **virtual** and augmented **reality** simulations increase student motivation and improve collaboration and knowledge construction. [89]

Wearing VR headset, students can experience high-quality educational visualizations that have a positive impact on the whole learning process. VR can help students easily understand complex concepts, theories, and subjects. they are able to digest and retain complex information at a much higher rate. [90]

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Educational Virtual Reality tools

Tool	Description	Pros	Joinable without HMD	PowerPoint	Cost
AltSpace by Microsoft	AltspaceVR is the premier place to attend live shows, meetups cool classes, and more with friendly people from around the world. (AltspaceVR)	- Simple event templates with descriptions, imagery, and pre-made environments designed. - Handle large participant (as many as 40,000 people in a single event.)	Yes, 2D mode on PC.	Yes	Free
ClassVR	The world's first virtual reality set designed specifically for schools, ClassVR provides teachers with everything they need to deliver engaging VR lessons. (AR VR Journey)	- Training for teachers, educators. - Technical setup support for organizations. - Designed specifically for schools	No		Depend on specific requirements.
Mozilla Hubs	Share a private virtual room with friends. Watch videos, play with 3D objects, or just hang out. (AR VR Journey)	- Popular in the Scientific Community	Yes, joinable via web browser	Yes	Free
Rec Room	The virtual social club. Play and build games with friends. (AR VR Journey)	- Possibility to build your own room. - Cross-platform	Yes	Yes, Share Desktop	Free

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VRChat	lets you create, publish, and explore virtual worlds with other people from around the world. (AltspaceVR)	- Very popular in the VR Community - Open Source SDK - Different Avatars - Full body avatars - Possibility to customize your own avatar. - Interactable objects (like a Pen, Sticky Notes)	No	Exported as pictures Tutorial	Free

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General Digital Educational Tools

Digital Education is growing rapidly on the last few years, and Universities must adapt to these new forms of teaching. Furthermore, with Covid-19 global Pandemic most training providers all over the world are turning to Digital Education as a solution to tackle the adversities caused by this catastrophe.

In this chapter will be summarized the main Digital Educational Tools that allow teachers to present the classes.

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General Digital Educational tools

	Functionalities	TEAMS	Discord	ZOOM	Moodle	Google Classroom	Skype for Business
1.	**Invite participants**	• An account or an email address is required for sign in	A link and a passcode that is given to the participants	• the students need to receive the credentials (ID and password) in case of each meeting in preamble • Only authenticated users can join	• The students need to receive credentials, the subject admin adds the students to the system	• The students receive a code of the class previously created by the teacher	• Micros oft account or guest access. Participants can join via a link.

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2.	**View and organize classrooms**	• Add or remove members • Create a new channel • Use a link or a code to join the classroom	• Participants subscribe to a channel after registering • Participants must choose and use their real name in the channel for transparency	• Add or remove members • Enable waiting rooms • Use a link and password to join the classroom	• Add or remove members • All the students existing in the system can be added to each individual classes by the teacher	• Add or remove students • Add or remove teachers working in collaboration	• N/A
3.	**Online courses**	Video and Audio calls	Audio calls and screen sharing	Video and Audio calls	Jitsi plugin can be added to each courses, which enables video and audio calls and screen sharing	Video and audio call possible with the extension Meet	Synchronous communication only
4.	**Work with files**	Send/receive materials to/from students (in general or private)	Send and receive materials privately or on the channels	Share screen of materials to/from professors / students (in general or private) / send/ receive of materials using Zoom Cloud	Send and receive materials with a lot of possibilities and restrictions	Send and receive lesson materials from Google Drive and Google Forms	students can download presented PowerPoint files

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5.	**Interactive communication**	• Group or Private chat • Type @team to message everyone in a team	• Group or Private chat Type @team to message everyone in a team	• Group or Private chat • Type @team to message everyone in a team • Raise hand option	• Group or Private chat	• Group or private communication • Private comments on courses, assignments, grades	• Audio-Video or text communication possible during conference call

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6.	**Assignments and Grades**	• Teachers creates and distribute assignments • Students can complete and turn in their assignments • Teachers can use the Grades tab to provide feedback on assignments and track student progress. Students can see their progress	A different platform (e.g. FTP server, Bitbucket, Gitlab etc.) must be used for submitting the assignments, since Discord does not offer such support	• Assignments and work progress can be monitored using Cloud feature option of ZOOM • User management allows account Owners and Admins to manage their users, such as add, delete and assign roles and add-on features.	• Assignments with a lot of formats and possibilities can be created by teachers such as: calculation examples with individual tasks, personalized questions, forms • All of the assignments are corrected automatically except essays • Each assignments can also be graded individually • The results are visible only for the designated student • The teacher can analyse statistics and performances of the whole class, and also sees the amount of time spent for each assignments • Also additional materials can be uploaded for the help of the students, such as games, definitions, forums, wiki, etc.	• Teachers creates and distribute assignments (Quiz assignments, assessments). A certain period of time can be allocated for each form using add-ons like Form Limite or Timify. Also forms can be customised to provide feedback either for wrong answers or right answers helping students to improve their knowledge • Students can complete and turn in their assignments and c they can see their progress.	• N/A

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7.	**Schedule online meeting**	Using Teams Calendar: a meeting can be schedule and all the members will receive an alert	Meetings are organized privately in the chat or in a public manner on the channel	Scheduling a Meeting with Google Calendar / Outlook	Message is sent through Moodle system and by email of the scheduled meeting	Schedule a Meeting on Meet using Google Calendar	It is possible to schedule a conference call
8.	**Share screen/Whiteboard**	Desktop, websites, presentations, videos, files, etc.	Share screen is supported	Desktop, websites, presentations, videos, working with White Board, etc.	With Jitsi plugin desktop can be shared	Desktop, websites, presentations, videos, files, etc.	Yes
9.	**Recording the meeting** **(video, audio, chat)**	√	No	√ Recordings can be stored on computer or on Zoom Cloud	√	Recordings available only on Meet	Yes

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10.	**Participate in a meeting**	Select Join from Teams calendar or directly from the group	Participants must sign in themselves in the meeting	Students needs to access: https.//join.us/link (on computer) or ZOOM application (mobile phone) and they are simply using the credentials (ID and password) that they have received	The meeting appears as a task for each student	Students receive an invitation in their email address and they can simply press “Join” button and they are in. Can be customized for email addresses inside an institution	Yes
11.	**Online meeting up to**	200 participants	30-40 people	100 participants (but can be up-graded to more participants (up to 1000) if necessary)	30-40 people	100 participants and for a 24 h time limit	250
12.	**Offline working**	√	No	√ (with the access of the admin)	No	√	N/A

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13.	**Versions**	Browser, Desktop, Mobile	Browser, Desktop, Mobile	Browser, Desktop, Mobile	Browser, mobile	Browser, Desktop, Mobile	Cross-platform
14.	**Other useful functionalities**	Background blurring or changing for video calls	• One can see at any time who is online (available) • Enable push notifications • Get notifications per e-mail Easily search for people	Video Webinars, Join by Toll-free dialing or Call, Skype for Business (Lync) interoperability, advanced meeting controls, such as enabling and disabling recording, encryption, chat and notifications, Choose Virtual Background, Switch to Phone Audio	This software is designed for online education with s lot of function for assignments, grading, teaching. Classes can be subdivided to smaller groups for special assignments.	• Enable push notifications • Get notifications per e-mail • Managing more classes from different specializations and different years of study	Participant management

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Conclusions

With technology comes evolution. This is valid maxim that applies to the generality of human developments. On today's time we are experiencing a paradigm swift and Industry is rapidly evolving into a new organizational model and a disruptive change is being experienced, which some call the "fourth industrial revolution".

Industry 4.0 and Digital Manufacturing are influencing industry towards a more efficient, automated and robotized industry. DIGIMAN proposes to tackle the Educational niche created by the significant increase of application of new Digital Technologies in manufacturing.

In order to tackle the needs in terms of knowledge, skills and competencies of the afore mentioned niche, Consortium Partners started by evaluating the features of this technological revolution. Industry 4.0 is built upon 4 principles Interoperability Information transparency, Technical assistance and Decentralized decisions. This are critical factors to consider upon the creation of a Master's course in Digital Manufacturing.

Furthermore, Partners evaluated the technological fields that compose this Industry 4.0 concept. Hereinafter are summarized the fields which a Digital Manufacturing Master should address: Internet of Things (IoT), Cyber-physical Systems (CPS),Vertical and horizontal integration system, Additive manufacturing (3D/ 4D printing), Big Data and Data Analytics, Cybersecurity, Cloud and edge computing, Simulation software, Autonomous robots & vehicles and Augmented & Virtual Reality.

Being Digital Manufacturing under the umbrella of Industry 4.0 technologies all the afore mentioned technologies shall be considered for inclusion in a Digital Manufacturing Master's course.

The concept of smart factories changed industrial thinking and highly influenced industry. From the combination of organizational sciences, such as Lean Manufacturing, Total Quality Management - TQM, and Concurrent Engineering emerged the concept of Digital

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Manufacturing that highlighted the need for more collaborative product and process design.

In order to validate and complete the data collected from the initial analysis, Partners conducted a research and assessment of the existing Digital Manufacturing Masters and related courses in consortium Countries.

The following fields were highlighted from the research: Industrial Production Technologies, Industrial Control Management and Operations, Digital, Technological and Communication. In order to have a an overview of the researched courses, hereinafter are listed some of the content lectured: Industry 4.0 concepts, Industrial Engineering, Industrial Digitization, Additive Manufacturing processes, Direct Digital Manufacturing processes, Automation and Robotics, CNC programming, Logistics, Project Management, Digitization processes, Digital Transformation, Cybersecurity, IoT (Internet of Things), Virtual Reality, Augmented Reality, Artificial Intelligence, RPA (Robotic Process Automation), Design Simulation and Modelling, Mechanic Engineering, Information and communication technologies.

Followed by the evaluation of existing courses in the area of Digital Manufacturing, DIGIMAN Partners made an evaluation of which manufacturing technologies and competencies that are mainly foreseen in industry. This allows Partners to narrow the research previously conducted and sort out the content to be delivered in the Master's course. The technologies evaluated are the following: Additive Manufacturing, Computer Numerical Control (CNC), Laser Cutting**,** Plasma Cutting, Water Jet Cutting**.** Moreover, Partners also conducted a research and analysis of the competencies needed in industries that operate with Digital Manufacturing concept, being highlighted CAD, CAM, CAE, CAQ and CAPE.

Besides listing and analysing the technologies and competencies, Partners conducted a survey to validate the relevance of these needs. The conclusions were that all the technologies are being used in Digital Manufacturing industrial Companies, being highlighted Additive Manufacturing and CNC. Moreover, when it comes to competencies

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it is concluded that all the mentioned above are highly required in industry (al with over 50% usage).

After a characterization of the several topics to be addressed in the Master's course Partners were able to define the entry requirements/ background necessary for a student to apply to the Master. A Bachelor's degree in one of the following areas is required:

- Industrial Engineering
- Mechanical Engineering
- Electrical Engineering
- Electromechanical Engineering
- Materials Science
- Engineering and Management
- Logistics
- Computer Science

To cope with the identified fields of competencies mentioned before, DIGIMAN Master must take full advantage of existing Digital Educational tools. Hereinafter, the tools identified by DIGIMAN Consortium are summarized and later in the project will be assessed and decided which tools to use.

- Augmented Reality tools - Vuforia, ARKit, ARCore, VisionLib and Wikitude;
- Robotic tools - Lego Mindstorm, Boe-Bot, The MiniSkybot, VEX robotic platform, Fable, Alpha Bot2 robot, Linorobot, Makeblock, Ultimate Robot Kit, The Speechi robotics sets, The BIOLOID;
- Educational Virtual Reality tools - AltSpace by Microsoft, ClassVR, Mozilla Hubs, Rec Room, VRChat;
- General Digital Educational Tools – Microsoft TEAMS, Dicord, ZOOM, Moodle, Google Classroom, Skype for Business.

The results encountered in this report and highlighted in this conclusion highly contribute to the next steps of DIGIMAN project, namely the definition of which areas to focus the DIGIMAN master's curriculum and the tools to be used during the course's lectures.

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Annexes

Annex 1 Digital Manufacturing Masters

DIGIMAN_IO1_T1_Annex1_Table Digital

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