Output 4

CHAIN

Higher Education Guidelines

Co-funded by the
Erasmus+ Programme
of the European Union

Project partner organizations

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Project name
Changing SME business by industry 4.0

Project acronym
Chain Project

Project number
Project No 2018-1- PT01-KA203-047330

Project duration
01.11.2018 – 31.10.2020

Co-funded by the Erasmus+ Programme of the European Union

This project has been funded with the support of the Erasmus+ programme of the European Union.

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1. Abbreviations and acronyms

AI - Artificial Intelligence

AR – Augmented reality

BM – Business Model

CAD - Computer-aided design

CEO - financial Officer Chief

CPS – Cyber-physical Systems

SME – Small and Medium-sized Enterprises

1. Introduction

The way we see the world changes radically with each new Industrial Revolution. The increasing use of steam energy, electricity, mass production and the insertion of programmable electronic devices marked the first three revolutions. The fourth, however, focused on the development of the internet, small, powerful and connectable sensors, increasingly sophisticated software and hardware, machines that learn and collaborate by creating gigantic networks of 'things', all at more affordable prices.

The Fourth Industrial Revolution profoundly changes the way we are, live, work and relate. This change affects the future of work, creating business models, requiring a reformulation of production, consumption, transport and logistics systems, accelerating the transition from a resource-based economy to a knowledge-based economy. This reality requires new skills from people and recruitment patterns, which have an impact on widening the skills gaps in the labor market and requiring a response from educational institutions to fill these gaps

This document is the result of lessons learned in the CHAIN-project and aims to provide the basis for the necessary curricular change in higher education to accommodate the challenges raised by industry 4.0.

Throughout the project, the concepts of industry 4.0 (I4.0) and the state of the art were analyzed in the brochure and several case studies were developed to understand how SMEs are facing the reality of I4.0. Subsequently, the pilot course was developed based on a manual that aims to teach students and managers what I4.0 is, but also to prepare organizations in terms of technology and strategy for a digital transformation process. The implementation of the pilot course made it possible to draw lessons and conclusions on how to change the contents and methodologies of higher education courses.

Subsequently, a curriculum analysis was carried out in each of the countries of the institutions of the CHAIN-project, in order to identify programmatic and curricular gaps in higher education courses, taking into account the requirements of I4.0.

At the same time, a set of reports was analyzed and crossed with the lessons learned from the CHAIN-project to build suggestions that can improve the curriculum development in higher education institutions.

1.1. Why Guidelines?

In addition to the conclusions and outputs of the project, the lessons learned can help higher education institutions and Vocational Education Training (VET) a guideline to have a clear strategy for the development of new curricula. Especially, since I4.0 involves transversal concepts that are not always addressed in the curricular structures (current curricula was created to train technicians and managers of the 3rd industrial revolution and not the fourth). These suggestions provide a better picture of what the desired future should look like and change from a reactive to a proactive approach, preparing students for lifelong learning, offering a 'global education', bearing in mind how the future Work will evolve, actively involving students in the development and implementation of the curriculum while respecting their diversity.

At the same time, these guidelines can improve the learning environment, both physical and virtual. I4.0 calls for problem-based learning in encouraging students to work on challenging real-life problems, contextualizing their theoretical learning in practice and thus avoiding standardized thinking and stimulating creativity. So I4.0 places the emphasis on creative and problem-solving skills, as standardized responses are developed by machines. These new learning environments can offer experiences relevant to the working conditions of the real world. Examples for this are that trainees getting physically and / or virtually involved in a factory environment, featuring modern and state-of-the-art equipment and encouraging collaborative learning, whether physical or virtual. Tools and methods for this are, among, others: Massive Open Online Courses (MOOCs), m-learning, gamification, Virtual and Augmented Reality, Artificial Intelligence.

Finally, curriculum content must be adapted to include technical concepts such as machine learning, data science (students and workers are taught how to acquire knowledge of the growing data "ocean" and how to find out what to do with it when found), additive manufacturing, intelligent materials, Artificial Intelligence, Internet of Things, predictive analysis, virtual and augmented reality technologies. But also, non-technical disciplines such as communication, project management, creativity, innovation, and business model management.

To guide through this multitude of different topics, this document is divided into 6 sections. The first one, the introduction provides a short overview about the guidelines, followed by the second reflecting on Higher Education (HE) and I4.0. The third section addresses the lessons learned within the CHAIN-project like skills requirements, where in the fourth the gaps in available curricula facing the required skills for the "smart factory“are identified. The fifth section involves suggestions for developing CHAIN-based curricula and methodologies in HE to present conclusions and implications for higher education institutions and VET in the sixth section.

1.2.2. New Higher Education Competencies and I.4.0

The great ongoing changes generated by the 4th industrial revolution in terms of skills bring challenges to higher education.

Data presented by Lorenz (2015) anticipates that in Germany, by the year 2025, approximately 610.000 jobs related to assembly and production will be lost, but an estimated increase of 960.000 new positions related to Information Technologies, with a net increase of approximately 350.000 jobs.

It is essential that new students and workers have the necessary accompaniment and instructions to be able to adapt and work together with new services and new technologies in new professions.

People will have to be trained on new technologies to achieve the fusion between human beings and machines to be possible and achievable. This fusion is necessary to reconcile the automation of production processes, the mastery of the tools to use cyber-physical systems, as well as the resources computational. I4.0 does not intend to eliminate workers for production, but its approach is to carry out complementary work, where human beings and automated systems are related to achieve improvements in production.

Areas such as information technology (IT) and engineering are fundamental during the integration of I4.0, since information technology is linked to the development of the latest technologies and the development of computer systems, namely artificial intelligence. Engineers are responsible for making machines and physical systems, as well as for connecting computer systems to machines.

On the contrary, there are jobs that technological developments cannot integrate into machines and which require human intervention, are called non-routine tasks and are divided into two groups. The first category deals with "abstract" tasks that require skills such as intuition, creativity and persuasion to solve not normally daily problems, for which trained workers, specialists with analytical and communicative skills in both, are employed. The technical field as management, has been important for decision making. The second category, called "manual" tasks, requires skills of adaptation to situations, language perception, ability to interact with the natural environment, people and the surrounding, based more on direct treatment to solve specific needs of each user.

Consequently, I4.0 raises the need to invest more in basic engineering sciences, such as computing, electronics, and machine engineering. The curriculum of engineering courses must consider the design principles of the Fourth Industrial Revolution, in addition to conceptual approaches through lectures and other training courses as part of the content to be explored. Familiarity with new technologies is necessary to create a vision for technological development.

The HE system needs a permanent transfer of knowledge for the development of the required skills. Cooperation between companies and universities is expected to expand in the coming years, especially in engineering, due to the lack of skills in production sites. A basic understanding of information management and data science (along with the ethical and legal issues involved) is critical to the increasingly important topic of value creation, as well as to managing the needs for internal and external information. This role is emphasized as network economies become more common, but it also requires an understanding of cybersecurity and the strategic deployment of modern quality control tools.

Also ‘mobile learning’ and ‘e-learning’ are of particular importance for teaching since work processes are changing or are not even transferable. Learning must take place throughout the process and educators must be trained in this regard, producing data that can be analyzed automatically and instructing/teaching workers before they suffer the impact of digitalization. Learning processes can be triggered by data from cyber-physical systems resulting from work processes, which allows mobile training in work settings. A teaching approach that allows students to independently implement and test their own projects is important. Using the network infrastructure, students gain knowledge of emerging industrial technology and become actors in the industry.

Preparation for I4.0 involves the development of digital skills and the establishment of technology education programs. At the same time, with routine tasks to be automated, the future workforce needs to be prepared to take initiatives, generate creativity, and make decisions. In this way, interdisciplinary knowledge is necessary to develop creative solutions to complex problems. This type of solutions does not always exist in universities, more centered on vertical specialization than on interdisciplinarity, giving a purely technological focus to engineering courses and a purely social / communicational focus to management courses. It is therefore essential that management courses include an understanding of technological culture and digital platforms, but also that engineering courses allow for a broader understanding of society, of business models of leadership, communication, and interpersonal relationships.

Therefore, personal skills such as strong oral communication and persuasion skills, critical thinking, coordination with others, emotional intelligence, judgment (as related to decision making), service orientation, negotiation and cognitive flexibility are fundamental. The European Reference Framework, defines 8 critical skills for the future: native and foreign languages, communication, mathematics, basic skills in science and technology, digital skills, learning to learn, social and civic skills, sense of initiative and entrepreneurship and culture awareness and expression.

These skills require continuous learning and the creation/management of multidisciplinary teams, who understand the interactions and possibilities of different technologies. Flexibility allows for mutual learning, better collaboration, and the creation of new solutions.

Self-knowledge and lifelong learning are essential for future work. HE institutions have a fundamental role to play in training of future professionals to shape these solutions.

Finally, knowledge about sustainability issues and existing solutions needs to serve as a guide for technological development. Understanding the impact of technology, locally and globally, needs to become a central consideration in the long-term decision-making process, especially when addressing scarcity issues becomes a necessity for everyone.

Nevertheless, there are some barriers to the implementation of these new concepts and ideas, linked with I4.0. Change is usually not rewarded in academic curricula. Most courses are evaluated by national agencies and these assessments require curricula stability through long periods. Considerable changes in curricula require the submission of new courses to these national bodies, which usually takes time and is a somewhat bureaucratic process. Hence, teachers/trainers typically do not get rewarded for introducing change and may even be "punished" for deviating from the agreed conventional approach. Without a support of national bodies or even HE management there is little incentive for teachers/trainers to develop and adopt innovations in curricula or in methodologies.

At the same time, the addressed multidisciplinary is also a barrier, since academic institutions tend to specialization in courses (BA, MsC, PhD) but also in organization So departments like computer science , mechanical engineering, Business Administration and Electronic Engineering normally interact seldom with each other, which is the opposite of what have been discussed.

At the same, there is a lack of access to infrastructure and the need for high capital investments in machines, IoT, new materials, etc. Many of the education and training providers therefore cannot afford buying state-of-the-art equipment.

Finally, most teaching methodologies are more or less archaic, focusing on a passive delivery of contents, while I4.0 requires problem solving, creativity and systems thinking. The ultimate goal should be to cultivate innovative people able to grow their autonomy, self-efficiency, and foster an entrepreneurial mindset.

This need has increased with the emergence of the Pandemic in 2020. The sudden impact of changes in routines at work, in study, in relationships, in needs, in these times of social isolation, provoked ruptures with ingrained habits and reflections on what is essential and what is superfluous, as well as requiring patience, developing activities differently.

The use of virtual resources has come into focus and its qualities and problems are being experienced. All of this has shaken convictions and comforts regarding the senses and the meaning of the formation of future generations. The question of the human in and with his environment has emerged, which in itself links to what this project had already found out before this situation. Work and education were already being transformed by digitalization. The virtual classroom is an opportunity to prepare students to new forms of work, to interact with tools that would already be fundamental in I4.0 world.

1.3.3. Lessons learned with the CHAIN-project

Different steps of the CHAIN-project allowed us to refine the concepts of I4.0 and understand how SMEs are adapting and developing digital transformation strategies.

We were able to discern that successful digital transformational routes required systemic thinking, a new vision and adapting the business model to accommodate new technologies to create value in a different way. At the same time IT related skills begun to permeate all industrial tasks, demanding SME to train staff and hire professionals with a different set of skills. Increased automation, use of CFS and network capabilities lead to different type of factory (smart factory), that requires knowledge of data analytics, communication technologies as well as knowledge on advanced digital manufacturing.

With the help of our brochure, the lessons learned from our case studies we designed a teachers manual, that encompassed the multidisciplinary we discussed on the previous chapter, that takes into account technologies that come from different engineering fields (robotics, communication, mechanical engineering, computer science, etc) as well as management and innovation concepts. The CHAIN-Course was an innovative learning opportunity for empowering, extending and developing the knowledge and competencies of HE students and SMEs (managers and owners) for assisting their role in meeting the needs of companies towards I4.0. This course and manual included main concepts and history of I4.0 (allowing students to understand impacts, benefits, obstacles and requirements to change), strategy for I4.0 (allowing students to understand new business models and how to create an organizational roadmap), followed by the identification of the technological and human dimensions needed to implement I4.0. Finally, students were required to implement a pilot project, to use these concepts in practice.

From these projects we learned that this complex reality requires a new approach to skills and competencies. Understanding new technologies is necessary to create a vision for technological development and is as important as investing in training in engineering concepts. These concepts are among others programming, data science, human-machine interfaces, data communication and networks and communication protocols, additive manufacturing, machine learning/artificial intelligence, IoT, advanced simulation and virtual plant modelling, cloud solutions, to name a few. We understood that the learning processes can be triggered by data from cyber-physical systems resulting from work processes, which allows for the creation of new products, strategies or business models. Using the smart-factory infrastructure students become actors in the industry, generating new solutions and understating interactions and possibilities of different technologies.

At the same time, skills such as strong oral communication and persuasion skills, critical thinking, problem solving, flexibility (emphasized by the fact change is faster) that teamwork, decision making, service orientation, negotiation and cognitive flexibility were fundamental, in a setting that allows for continuous learning and the creation.

1.4. 4. Gap Analysis

A quick analysis was conducted in France, Bulgaria, Portugal and Austria. We analyzed higher education courses curricula in engineering, management and social several sciences. Nevertheless, this document does not present an exhaustive list of training around Industry 4.0 The analysis made is based only on a monitoring work and on the interpretation of the training programs provided online.

We found out that:

- Most social sciences degrees did not have any mention of Industry 4.0. Nevertheless, some addressed innovation (and its management), technology management and several soft skills important for Industry 4.0
- In terms of engineering and management there are several master's and specialized courses (in Portugal, France and Austria) that not only address several Industry 4.0 dimensions, but that are focused in it (such as "Master's degree - Industrial Engineering 4.0", "Master's Degree Industrialization Manager 4.0", Master's degree – Digital Transformation for Industry, Master's degree – Industry 4.0 and smart systems)
- Nevertheless, some course do not address all technological topics (most often Big Data, VR, Cybersecurity, AI and some additive manufacturing) but technological focuses courses lack topics in Change Management or overall topics in Management and Psychology)

1.5. 5. Suggestions for developing CHAIN-based curricula and methodologies in HE

Based on the previous sections, the gap analysis conducted on the countries of the CHAIN-Consortium, several studies described in our reference list and several European reports, we compiled a list of competencies that should be part of the curricula of higher education institutions in order to prepare students that are a better fit in a I4.0 world.

We divided our suggestions in 3 discipline specific competencies – engineering, management, and innovation. Though engineering competencies are little more complex to implement in specialized engineering courses, but we consider that all of them should address, more or less, these topics (in a more intensive or less intensive manner, taking into account each engineering specialization). Suggestions for management and innovation include a perspective that is more in line with the current specialization.

At the same time, we propose behavioral competencies, that are not discipline based, but should be taught/trained in any type of course, in order to prepare a workforce that is more adapted to the new reality.

Table 1 – Competencies for Industry 4.0

Discipline Based Competencies			
Engineering	**Management**	**Innovation**	**Behavioural Competencies**
Advanced Data Analytics	Change Management	Design For Human-Machine Interaction	Soft Skills (Ability To Work In Teams, Leadership, Networking And Social Skills, Communication Skills, Negotiation)
Human-Machine Interfaces	Business Strategy And Business Models	Design Thinking	Problem-Solving Skills
Digital-To-Physical Transfer Technologies	Digital Skills	Creativity	Systems Thinking
Data Communication And Networks And Communication Protocols	Communication	Ergonomics	Technological thinking
Digital-To-Physical Transfer Technologies (3-D Printing)	Innovative Leadership		
Advanced Simulation And Virtual Plant Modelling	Tech-Enabled Processes: Forecasting And Planning, Metrics, Scheduling		
Closed-Loop Integrated Product And Process Quality Control/Management Systems.	Talent Management		
Artificial Intelligence And Machine Learning	System Analysis		
Robotics	Sustainability		
Real-Time Inventory And Logistics Optimization Systems	Knowledge Management		
Automation	Technological literacy and comprehension		
Programming			
Mechatronics			
Cybersecurity			
Augmented And Virtual Reality			
Iot			
Cloud Solutions			

1.6. 6. Discussion and Conclusions – implications for VET and HE

Future education for I4.0 will have to offer an engaging learning, using active methodologies. Through them, the student stops passively assimilating knowledge and is constantly instigated by teachers - who gain the role of mentors - in the search for answers and problem solving.

This new model of education (Education 4.0) is centered on the concept of "learning by doing". The model prioritizes student self-development and the construction of values, knowledge and skills based on the experience of different activities. Learning happens faster and more richly when it occurs through practical experiences and activities called "hands-on." Even better if they happen in maker spaces, another concept of innovation. The goal of "hands-on" activities is to make learning more meaningful to students, and this can happen even through recyclable items and scrap. What is at stake in this type of exercise is the construction process, and not necessarily the product.

But at the same time technology emerges as an asset to make learning flexible and increase. In Education 4.0, the quality of technological teaching platforms is almost as important as that of teachers. Therefore, managers must have a thorough knowledge of the educational software available on the market. Only then will they be able to choose the most coherent solution for the reality of the institution. The virtual learning environment (VLE) and adaptive teaching platforms are part of this.

In addition to the use of active methodologies, another important instrument of innovation in Education 4.0, especially in higher education, is hybridity in teaching. The mix of face-to-face meetings and technology-mediated activities has already demonstrated that it optimizes learning and is better suited to students' needs. The model advocates the integration of on and offline approaches to create an environment conducive to education based on experience. It goes beyond simply inserting smartphones and computers into the classroom.

Hybrid Teaching proposes the joint use of resources that really stimulate students' digital skills and intelligence. The practice even has its own environment to happen: they are called makerspaces - spaces for creation. The makerspaces are an experimentation laboratory, equipped with several resources - from saws and wood cutters to 3D printers and programming software. Also known as innovation hubs, these environments encourage the development of products and projects, encouraging students to be creative and tolerant of error.

An important point for the adoption of the maker culture in HEIs is to associate practices with interdisciplinary projects, which can not only develop students' socio-emotional skills, but also offer improvements for society. In addition, the tool stimulates the ability of students to deal with new technologies and innovations. This, by the way, is not a challenge restricted to students.

The curricula also should be updated with I4.0. They become much more transversal, eliminating the idea of disciplines separated by "boxes". After all, knowledge is not built in a departmentalized way.

Implementing the innovations provided for by Education 4.0, however, requires change. The first and most essential is the training of teachers, who continue to have a relevant and fundamental role in teaching the future. Such professionals will have to have wisdom and qualification to deal with both new technologies and different pedagogical methods. Educational institutions must also adapt their infrastructure. In addition to investing in technology for remote teaching and learning, it is worth redesigning the classroom for face-to-face activities. Maker spaces where students can create prototypes and experiment are important allies of innovation. The result is the formation of a more autonomous student, with critical thinking and much more prepared to face the challenges of the labour market.

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