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THE EVOLUTION OF STUDY PROGRAMS IN ROMANIAN TECHNICAL HIGHER EDUCATION IN RECENT YEARS

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Abstract: *The purpose of this article is to emphasize the evolution of study programs in the Romanian technical higher education field according to labor market requirements along with the development of the Industry 4.0. In this respect the whole education system, including the higher education area, faces significant challenges in fulfilling their role of training the future graduates who will have to own the necessary skills required by the industry developments. The main objective of our research is to explore the study programs development from 2018 until 2022, by analyzing each technical study area according to the Romanian legislation in place. The analysis covered 40 Romanian universities and 18 technical study areas, resulting 6828 technical study programs. As one knows, the main challenge of the traditional education system has always been the way of transforming students into a well-prepared labor force owning the right skills. This represents the first step to access a suitable job on the labor market. With the emergence of Industry 4.0, the new demanded jobs require universal specialists having specific technical and essential skills in a specialized field, being able to be flexible to rapid technological changes and flexible to interaction with automated machines and robots. The study programs analyzed in this paper highlight the evolution of technical higher education study areas in the direction required by Industry 4.0 allowing graduates to access new occupations at national and European level.*

Key words: *Industry 4.0, Education 4.0, study programs, skills, occupations.*

¶

1. INTRODUCTION [1]

The technical higher education field experiences various updates in the light of changes brought by industry shift in recent years. Everywhere one can hear about the Forth-Industrial Revolution, also called the *Industry 4.0 phase*. In 2011 Kagermann [1] introduced for the first time this term and explained how the paradigm shift in industry will take place, by using advanced technologies such as: Internet of Things, cyber-physical systems, augmented reality, virtual reality, big data, autonomous robots, additive manufacturing and also machine learning, and others [2].

Over the years, the revision in the field of industry influenced all related fields, specially the work life. Every change in the industry has an impact also on people and their needed skills, abilities and knowledge to become the workforce of the future. People will have to learn to work with new technologies implemented by Industry 4.0 by firstly updating their knowledge, skills and competencies [3]. This requirement of work-skills improvement influences also the way universities in the technical field develop their curricula and study programs, but the major expected changes will take place between 2030 and 2050 [4]. Universities will have to take into account what is now needed on the labor market, and use this information to adapt and develop the study programs, taking into account that the human workforce is always in the center of the system and also that students need to adapt to new technologies and to own self-development capabilities [5].

2. INDUSTRY 4.0 AND EDUCATION 4.0

2.1. Industry 4.0

As is known, the development of an industrialized society was made in three big steps:

- First step, year 1780, was the so-called *First Industrial Revolution*, characterized by the invention of the steam engine, use of machines for good production etc.
- Second step, year 1900 – *Second Industrial Revolution* – was marked by the discovery of electricity, which led to a series of developments in the chemical, electrical, oil, and steel industries, airplane development, mass production of goods, etc.
- Third step, year 1970, *Third Industrial Revolution*, is characterized by computers, automation, information and communication technologies development.
- Today a forth step is taken belonging to the era of the *Fourth Industrial Revolution – Industry 4.0*.

The term *Industry 4.0*, which refers to changes in the automation fields integrated with information technologies [6], appears in the context of a new industrial revolution, in order to emphasize the latest technological innovations in production sector [7].

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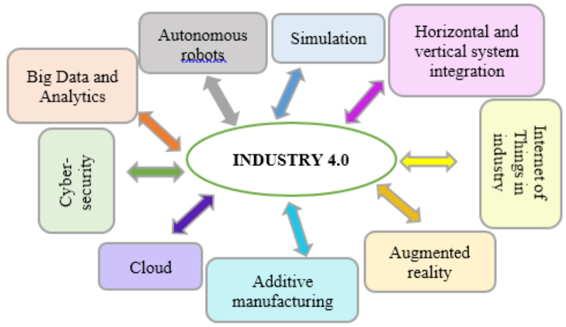

Fig. 1. Industry 4.0 characteristics, adaptation from [6, 7].

Researchers and specialists in the field set out the *Fourth Industrial Revolution* as an integration of the production processes with cloud computing, adding artificial intelligence in this combination applied to machines [8].

According to Kagermann [6], Industry 4.0 represents a technical challenge that brings also changes in the structure of companies: autonomous production, development of smart products that help optimizing the production processes, flexible production for customized products, autonomous control and others, Fig. 1.

A simple and comprehensive definition of *Industry 4.0* can be found in [7] where is stated that it represents a business environment that links up by means of cyber-physical systems and using the internet, machines, devices, employees and other business systems. It is a demonstrated fact that new technologies developed in Industry 4.0 will significantly improve the quality of products and services provided by companies using autonomous and dynamic production [8].

However, without well-trained workers, possessing permanently updated skills, Industry 4.0 will not be able to advance to what is expected to be – a next level of cooperation between man and smart machines with the help of robots, *Industry 5.0*.

2.2. Education 4.0

To be able to understand the current state of education, one must know the steps taken so far [9]:

- Firstly, *Education 1.0*, characterized by informal teaching, religious-controlled.
- Secondly, *Education 2.0* marked by the development of educational institutions.
- Thirdly, *Education 3.0* which integrates information and communication technologies. Education is now becoming somehow accessible without time, place, and space constraints by using of Massive Online Open Courses, Corporate Online Open Courses and Small Private Online Courses.

The fast shift in the industry nowadays induces changes in the field of education, so *Industry 4.0* is strongly dependent on a so called *Education 4.0* system combined with lifelong learning, so that the needs of industry and workforce market are met and a balance for sustainable growth is achieved [10].

The fourth industrial revolution has a great impact on digital transformation and organizational integration [11], on the development of artificial intelligence, augmented reality, cyber-physical systems, and Internet of Things, in order to improve life quality that brings along the need for workplace transformations, leading to the core of skills development, namely the educational system.

Nowadays, the future workforce has to be well trained and equipped with interdisciplinary skills, which enables reflective thinking [12]. In other words, in order to achieve an intelligent society education, one needs to change its traditional form, needs to implement new tools, software and hardware. All these integrated with artificial intelligence, virtual reality, and high technological training for the development of a new society, namely *Society 5.0* [13].

Researchers in the field indicate that a new form of educational system must be set in place, namely *University 4.0*, Fig. 2. This new system must integrate learning opportunities through blended, online and traditional ways, and short-term education programs as well as lifelong learning [14].

The educational path of each student in the technical field should be adapted and personalized in such way that everyone has the opportunity to accumulate, update or develop new skills and also interdisciplinary competencies that will help enter the Industry 4.0 labor market after graduation.

In order to prepare future learners for adapting to the fourth industrial revolution, it is necessary to align education with Industry 4.0 [15]. In this respect all technological advances, such as 3D-printing, artificial intelligence, virtual reality, cloud computing and so on, must be integrated into the educational process [16].

Education 4.0 must be developed to create qualified professionals ready for a globalized and digital-driven world of work.

3. DEVELOPMENT OF STUDY PROGRAMS IN THE ROMANIAN UNIVERSITIES

The aim of the current research is to an the evolution of study programs in the Romanian technical higher education field according to labor market requirements along with the development of the Industry 4.0.

3.1. Methodology and data collection

The main objective of the study is the exploration of the technical study programs development by researching 18 technical study areas for each university, as stated in the Romanian legislation on a five years period from 2018 to 2022.

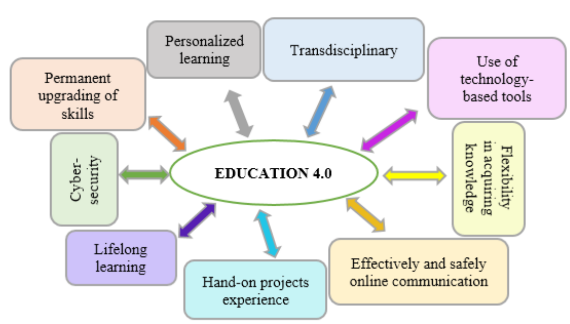

Fig. 2. Education 4.0 characteristics, adaptation from [17].

The current research was conducted in 40 universities according to the List of Public Higher Education Institutions from the Romanian Ministry of Education site included in the Government Decision (GD) No. 403/2021 with subsequent amendments. Authors also covered 18 technical study areas according to the Government Decision no. 433/2022 regarding the approval of the Nomenclature of fields and specializations/ university study programs and the structure of higher education institutions for the academic years 2022–2023.

3.1. Results

As previously mentioned, the authors gathered data from 40 Romanian higher education institutions, from the public and private sector. One analyzed a total of 18 study areas, in Table 1 resulting a total number of 6828 study programs (see Fig. 3). In Table 2, one can see the repartition of study programs for each study area taken into account yearly.

From the 18 study areas analyzed (Table 1), the ones that best outline the evolution of the study programs according to the requirements of Industry 4.0 are those marked.

Table 1

Technical study areas analyzed

Study area number	Study area	Importance according to Industry 4.0
1	Aerospace engineering	
2	*Applied engineering sciences*	■
3	*Automotive engineering*	■
4	Building services engineering	
5	*Chemical engineering*	■
6	Computers and information technology	
7	Electrical engineering	
8	*Electronic engineering, telecommunications and information technologies*	■
9	Energetics engineering	
10	Engineering and management	
11	*Environmental engineering*	■
12	*Industrial engineering*	■
13	*Materials engineering*	■
14	Mechanical engineering	
15	*Mechatronics and robotics*	■
16	Program and application systems engineering	
17	*Systems Engineering*	■
18	Transport Engineering	

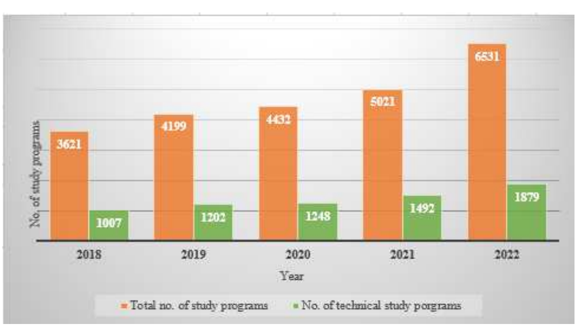

Fig. 3. Number of technical study programs per year.

Table 2

Evolution of study programs from 2018 to 2022 in the technical higher education institutions

	Number of study programs per study area				
	2018	2019	2020	2021	2022
Study area*					
1	18	18	18	32	35
2	31	49	52	65	75
3	39	43	46	51	62
4	8	9	9	10	12
5	61	67	70	77	124
6	56	74	76	87	119
7	69	80	83	97	125
8	88	111	116	135	172
9	41	49	55	77	86
10	118	135	143	172	206
11	80	91	93	111	147
12	115	142	143	165	199
13	38	47	48	60	68
14	86	100	106	133	167
15	33	39	41	52	63
16	60	71	71	78	102
17	54	65	65	74	98
18	12	12	13	16	19

(**see Table 1*)

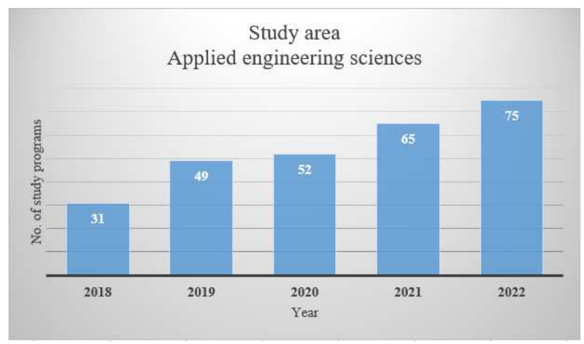

Fig. 4. Evolution of study programs developed for *Applied engineering sciences* study area.

Figure 4 presents the evolution of study programs between 2018 and 2022 developed for the study area *Applied Engineering Sciences*. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Industrial biotechnologies, Biomaterials and medical devices, Applied bioengineering for regenerative medicine, Nanoscience, Biomaterials and Medical Devices, Biomedical engineering, Smart biomaterials and applications and others.

Figure 5 presents the evolution of study programs in the period 2018–2022 developed for the study area *Automotive engineering*. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: The vehicle and the future technologies, Virtual Engineering in Automotive Design, Hybrid and electric vehicles and others.

Figure 6 presents the evolution of study programs per year developed for the study area *Chemical engineering*.

For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Science and Engineering of Oxidized Materials and Nanomaterials, Advanced Materials Processing and Design, Unconventional materials in modern biotechnologies, Innovative Technologies for Secondary Raw Materials, Chemistry and engineering of nano- and biomaterials, Biomaterials for tissue engineering and others.

Figure. 7 presents the evolution of study programs for the period considered 2018–2022 developed for the study area *Electronic engineering, telecommunications and information technologies*. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Microelectronics, optoelectronics and nanotechnologies, Cyber security, Biomedical electronics, Electronics of intelligent systems, Intelligent Transport Systems and others.

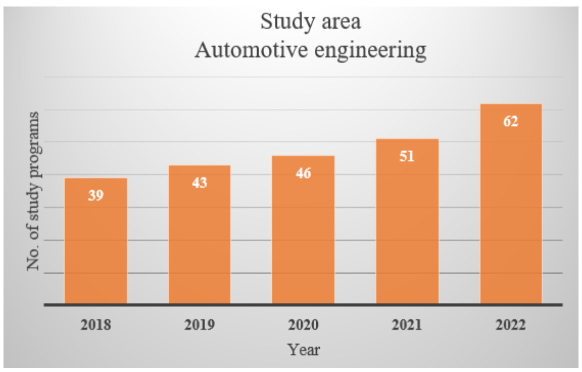

Fig. 5. Evolution of study programs developed for *Automotive engineering* study area.

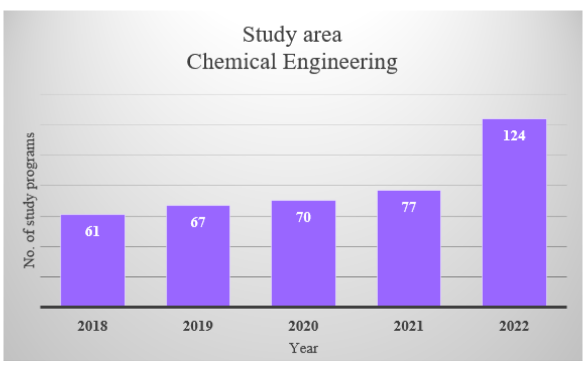

Fig. 6. Evolution of study programs developed for *Chemical engineering* study area.

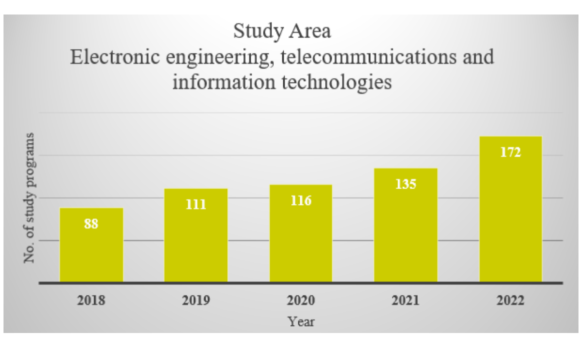

Fig. 7. Evolution of study programs developed for *Electronic engineering, telecommunications and information technologies* study area.

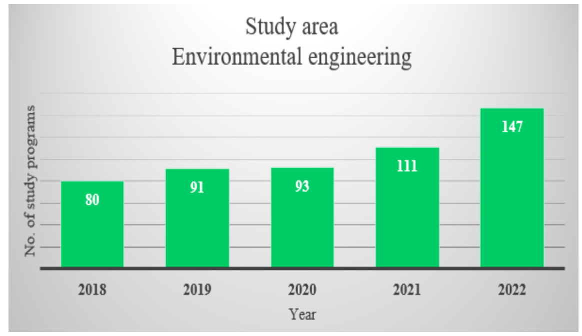

Fig. 8. Evolution of study programs developed for *Environmental engineering* study area.

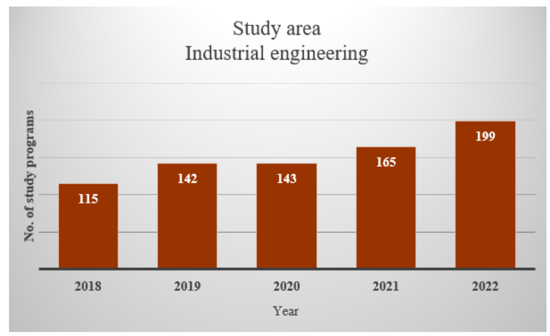

Fig. 9. Evolution of study programs developed for *Industrial engineering* study area.

The evolution between 2018–2022 of study programs developed for the study area *Environmental engineering* is shown in Fig. 8. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Biotechnical and ecological systems engineering, Sustainable development and environmental protection, Green and circular economy.

For the period considered, Fig. 9 presents the evolution of study programs per year developed for the study area *Industrial engineering*. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Digital production systems, Intelligent Manufacturing Systems and Technologies, The integrated concept of technological systems, Engineering of nanostructures and unconventional processes and others.

Figure 10 shows for the period 2018-2022 the evolution of study programs developed for the study area *Materials engineering*. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Advanced Materials Engineering, Nanotechnologies and multifunctional materials, Biomaterials engineering, Advanced metallic materials for hi-tech applications and others.

The evolution of study programs developed for the study area *Mechatronics and robotics* are presented in Fig. 11. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Ergo-engineering in mechatronics, Robotic systems with artificial intelligence, Mechatronics of biotechnical systems, Mechatronic systems for industry and medicine and others.

Figure 12 presents the development of study programs achieved for the study area *Systems Engineering* between 2018–2022. For this study area, in addition to the usual technical study programs, specific programs requested by the evolution of Industry 4.0 were also developed, such as: Automation and intelligent systems, Engineering the Internet of Smart Devices, Advanced automation systems and IT technologies, Advanced manufacturing management engineering, Robotics and automation, Intelligent control systems, Advanced control and real-time systems, Machine learning, robotics and control, Cyber physical systems and others.

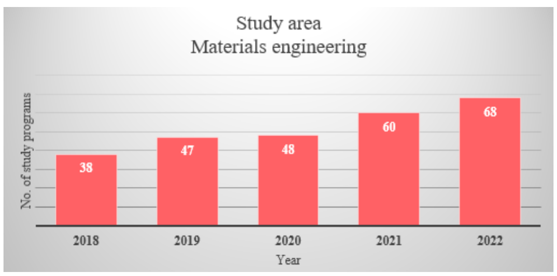

Fig. 10. Evolution of study programs developed for study area *Materials engineering*.

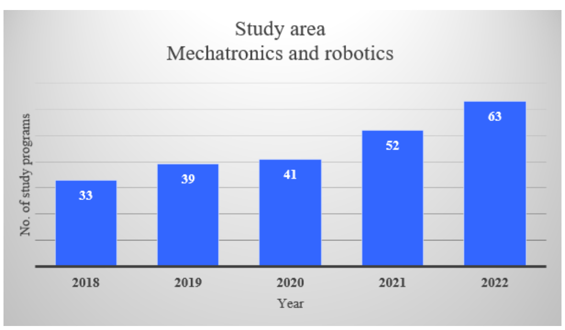

Fig. 11. Evolution of study programs developed for *Mechatronics and robotics* study area.

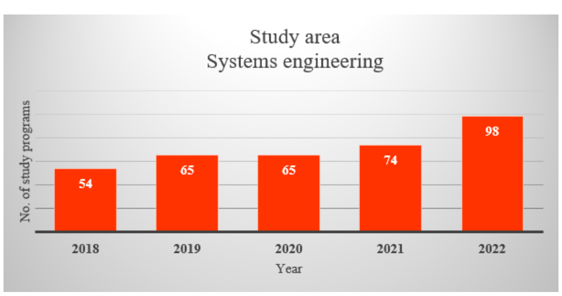

Fig. 12. Evolution of study programs developed for *Systems engineering* study area.

4. LABOUR MARKET AND ESSENTIAL SKILLS AND COMPETENCIES LINKED TO INDUSTRY 4.0

The main challenge of the traditional education system has always been the way of transforming the students into a well-prepared labor force owning the right skills. This represents the first step to access a suitable job on the labor market.

With the emergence of Industry 4.0, the new requested jobs require universal specialists having specific technical and essential skills for a specialized field, being able to be flexible to rapid technological changes and to interaction with automated machines and robots. In addition to these skills, Industry 4.0 increases the demand for soft skills, such as creativity, ability to solve complex problems, emotional intelligence, analytical thinking, adaptability to global environments and contexts. Specialists state that a continuous adaptation to labor market requests by skills and competences continuous improvement, and lifelong learning are the key. There must be continuous collaboration and communication and also mutual development between labor market and technical higher education system. It is now crucial that the labor market highlights the needs of the missing skills and has to be ready to also engage in training the specialists along with the educational system.

The study programs analyzed in this paper highlight the evolution of technical higher education study areas in the direction required by Industry 4.0 allowing graduates to access occupations at national and European level. Further, the study presents some examples of occupations and essential skills, competences and knowledge for each of them related to some study programs to emphasize once again the strong connection between university studies, graduates and the labor market applied to Industry 4.0, Table 3.

7. CONCLUSIONS

The specialized literature has a consent on the fact that *Education 4.0* represents the reflection of *Industry 4.0* on education. Education 4.0 is seen as an educational reform so as the requirements of Industry 4.0 are met, especially when talking about workforce demand. However, both Industry 4.0 and Education 4.0 are concepts that actually are not self-standing and in process of development and empirical research. One can tell for sure that Education 4.0 in not yet put in practice and for this to happen it is necessary to integrate continuous developing technology with education techniques.

On the other hand, there are significant development opportunities for Romanian education and labor market in the context of Industry 4.0. The industry direction is very clear for the moment and data management and cyber-security will be key issues to address. Next, in order to realize the true potential of Industry 4.0, companies must understand the urgency of digitization, make plans and apply them for fast digital transformation.

Table 3

Connection between study programs and occupations in the labor market for Industry 4.0 [18]

Study area	Study program	Possible occupations on the labour market (ESCO)	Occupation code (ESCO)	Examples of shared essential skills, competences and knowledge (ESCO)
Applied engineering sciences	Advanced materials and technologies for unconventional energy systems	• Smart home engineer • Home automation specifier • Domotics engineer • Smart home project engineer	2151.2	- design electronic systems - develop software prototype - perform ICT troubleshooting - assess integrated domotics systems - apply technical communication skills
Chemical engineering	Biomaterials for tissue engineering	• Tissue engineer • Biochemical technology engineering expert • Metabolic engineer • Enzyme engineer	2145.1.1	- conduct research across disciplines - biological chemistry - analytical chemistry - develop biochemical manufacturing training materials
Electronic engineering, telecommunications and information technologies	Microelectronics, optoelectronics and nanotechnologies	• Microelectronics smart manufacturing engineer • Smart production expert • Smart manufacturing engineer	2152.1.9	- cyber security - micro-assembly - principles of artificial intelligence - execute analytical mathematical calculations - integrate new products in manufacturing
Environmental engineering	Biotechnical and ecological systems engineering	• Recycling specialist • Recycling and waste reduction specialist • Waste management consultant • Waste recovery specialist	2143.1.3	- hazardous waste storage - waste management - ensure compliance with waste legislative regulations - identify new recycling opportunities
Industrial engineering	Engineering of nanostructures and unconventional processes	• Nano-engineer • Nano-systems engineer • Nanotechnology specialist	2149.11.1	- examine engineering principles - nanotechnology - design prototypes - computer engineering
Materials engineering	Biocompatible substances, materials and systems	• Biomedical engineer • Biomedical engineering specialist • Biomedical technology engineering expert	2149.5.1	- collect biological data - adjust engineering designs - demonstrate disciplinary expertise - biomedical engineering - medical devices materials
Mechatronics and robotics	Robotic systems with artificial intelligence	• Robotics engineer • Autonomous systems engineer • Robotics engineering expert • Control systems engineer	2149.15	- design automation components - engineering processes - human-robot collaboration - simulate mechatronic design concepts - use technical drawing software

The study programs analyzed in this paper highlight the evolution of technical higher education study areas in the direction required by Industry 4.0 allowing graduates to access occupations at national and European level.

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