Digital Competences of Engineers in Industry 4.0: Analysis of Industrial Informatics Study Fields at Technical Universities in the Czech Republic and Poland

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***Abstract* – Technological progress is faster than changes in education at technical universities, so it is a problem for universities that they are still somewhat behind. Based on research of sources dealing with digital competencies and requirements for specialists for Industry 4.0, the paper analyses the status of teaching industrial informatics in existing study programmes at technical universities in in the Czech Republic and Poland. The research question is whether the current state of education meets the requirements for Engineers 4.0. The analysis shows that there are three different specializations within study Industry 4.0. The first one is focused on data analytics and forecasting, the second deals with mastering advanced control methods and algorithms and the third area is directed towards production and technologies. Based on the analysis, the paper describes the key areas of digital competence in Industry 4.0 and define a recommended list of subjects for building a profile of Industry 4.0 engineer.**

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1. Introduction

Due to technological revolutions, the demand for engineers with digital skills is growing. Production and logistics processes in factories are increasingly based on digitally driven machine technologies.

Industry 4.0 technologies support in factories is becoming increasingly digital. Factories generate thousands of sensor data, which are used to optimize production and logistics processes with strong human support from Artificial Intelligence (AI). With the introduction of AI to the industrial environment, technology in certain areas allows machines to 'think' and replace operators. In smart factories, machines become more visible than their users (operators). The relationships of operators with intelligent technologies are different than the relationships of employees with traditional machines. In companies achieving increasingly higher levels of digital maturity, to an outside observer, human-technology relationships appear to be exceptionally complicated. In reality, they are simpler than work at production stations (manual operation of machines), but require digital skills. In the smart environment, employers' requirements for engineering staff are growing. In Industry 4.0, knowledge of computers, software, databases, data analysis, cloud computing services, Internet of Things (IoT), digital twin and other technologies are needed in cooperation human and technology [1], [2].

The concept of Industry 4.0, which was first formulated in 2013, includes new technologies: IoT and IIoT [3], cloud systems [3], cobots and autonomous robots [4], Big Data analytics [5], additive manufacturing [6], advanced control algorithms and optimisation methods, digital twins, and others.

The implementation of the latest generation of technologies in manufacturing enterprises is to lead them to smart manufacturing, which means "fundamental changes in organizations and processes" [7] and finally also of human work [8], [9]. In smart manufacturing human-automation symbiosis is needed [10], in "which humans and machines communicate with each other via both physical and virtual means" [11], [12]. Collaborative robots (cobots) support assembly workers. Autonomous robots take over human thinking and perform activities independently. Algorithms, pattern correlations, deep learning techniques, predictive analytics are increasingly used in production processes. There is a continuous transfer of data between technologies. Data from production technologies is delivered and analysed in real time and is used for analyses that are created using algorithms of autonomous decision-making systems [13], [14]. The human machine interactions are mentioned by [10], [15] and [16], where the operator is strongly involved with technologies. The employee operating new digital, autonomous and intelligent technologies is called "Operator 4.0" [10].

This paper discusses what competencies (skills) are needed for engineers in Industry 4.0. The input for the design of competence proposal is the analysis of study programmes at the Czech and Poland technical universities. The prepared analysis can be used for further development of study programmes in technical universities.

The paper consists of:

- Section 1: Digital competences: Background of analysis;
- Section 2: Current state of industrial informatics;
- Section 3: Industrial Informatics in study fields: Poland and the Czech Republic;
- Section 4: Key areas of digital competences for engineer of Industrial Informatics.

2. Theoretical Background

Artificial Intelligence, including algorithms, neural networks, machine learning, handwriting recognition, speech recognition, image recognition, fuzzy logic, credit scoring, forces a change in processes and structures in process control (management). Increasingly, humans without digital skills are being "excluded" from this environment. In addition, human jobs are being replaced by machines, bots (call centres), cobots and autonomous robots. According to the latest IFR report [17], there are over 3.4 million robots in use worldwide, of which the largest number of industrial robots work in the industries of electrical/electronics, automotive, metal/machinery, chemical and food [17].

A rapid increase in the number of installed robots occurred after year 2021. Report [19] states that the largest increase in robots is on the Asian continent (China, Japan, South Korea), and among the EU countries, Germany, Italy and France are in the lead [17]. In manufacturing enterprises, repetitive operations are performed by robots. Robots perform manipulation, transport, assembly activities. In addition, the development of the IoT, the Industrial Internet of Things (IIoT), and Big Data Analytics technology, makes them capable of learning from historical data and communicating with each other and with humans. Human (operator) skills in the future will be related to cooperation with Artificial Intelligence. According to the research conducted in [16], by 2030 almost 15 % of currently existing professions will cease to exist at all. In their place, other jobs will be created, which are currently referred to as 'professions of the future', such as: technology consultant, robot programmer, robot liaison specialist, cloud computing architect, data analyst with specializations such as critical data analyst, decision information analyst, data graph analyst, data risk analyst, organization cost analyst, sales analyst, customer profile analyst, etc. The article [18] analysed the offers for digital specialists on the labour market in Poland and the Czech Republic. Factories need, among others, robot operators, artificial intelligence specialists, computer network operators, computer application operators, computer network analysts, mobile application programmers, database designers, data scientists, cloud engineers, cloud network engineers, cloud system engineers, 3D printer operators, CNC operators [18]. According to the report [19], "in 2021 about 9 million people worked as IT/ICT specialists in the EU". The highest numbers were reported in Germany with 2 million ICT specialists (22.5 % of the EU total). The European market will be required 20 million of IT/ICT specialists by 2030. People will work in cyber-physical production systems (CPPS) with strong synergies of technologies. Cyber-physical production systems need more and more employees with digital competences. As stated in [20], the concept of 'digital intelligence' appears as a requirement for a good employee in a smart factory. This concept includes both skills related to the use of digital devices, even very advanced ones, as well as social, cognitive, interpersonal, critical thinking, and comprehensive problem-solving skills that allow employees and management to effectively cope with and adapt to the digital and physical world. Digital competences consist of technical knowledge, digital skills, and soft skills presented the system of employee competences in T-shaped skills [21], [22], [23], [24], [25], [26]. The letter 'T' is a combination of general competences and specialist competences.

This model is realized in many industries over the world. The employee's competences must result from their tasks, and therefore it is necessary to specify competences that "must have", "should have" and "can have". Digital and technological competences e.g., programming, data analysis, knowledge about essential technologies of Industry 4.0 and skill to operate with Augmented or Virtual Realities, IoT, AI, etc. In smart manufacturing, operators should have cognitive competences [27], [28], [29], [30]. The article [30] point to leadership in the development of digital competences of staff. The important group of competences required in Industry 4.0 are social competences (cooperation, communication, working in group, leadership, and emotional intelligence).

Digital competences (skills) of employees can be at the level of 'basic' and 'above basic'. The basic level includes general knowledge of digital devices that a person uses efficiently because they have already acquired digital skills. The 'above basic' level requires extensive or even specialist knowledge according to different areas of development of computer science and information technology. Enterprises need engineers with high digital competences. The report [31] indicates that competences should enable solving IT problems, designing cloud architecture, processing complex data sets, programming robots, building data analytics architecture, etc. It is predicted that by 2030, over 80 % of tasks related to process management will be provided by artificial intelligence systems. Science, Technology, Engineering, and Mathematics (STEM) are important for the education of engineering staff [32], [33]. The use of new technologies at the management level also requires cyber technology to ensure digital security and connectivity for enterprises. The paper [34] analysed the metallurgical competences in Poland and established the digital profile of engineers for steel industry ("Metallurgist 4.0"). The authors stated that competences of engineers must be more digital. In the future, the "Engineer 4.0" should have advanced digital competences that enable them to operate digital technologies, which should be supported by data analysis skills (knowledge of mathematics, econometrics, statistics) [23]. Digital technical competences refer to the practical use of science in the following fields: system integration, mathematical modelling, simulation, top-down production of nanostructures, etc. Advanced digital competences should provide engineers with the foundations for building smart innovations (creating a smart environment at workstations). Bottom-up process improvement is supported by innovations from R&D&I departments.

The area of innovation consists of R&D skills related to products and processes. In the field of process innovations, engineers can improve manufacturing technologies from simple (indicating places or objects for sensor installation) to advanced (nanotechnologies, Artificial Intelligence, photonics, digital security). In relation to products, innovations may concern RFID tags, as well as advanced materials and solutions such as smart products.

Digital competences are also needed to handle fully automated processes. In this area, a distinction can be made between process skills, quantitative reasoning and cross-functional skills. From repetitive operations in handling processes, engineers, with the increasing level of advancement of manufacturing technology development and support of production and logistics processes, move to programming robots and automation solutions. A modern factory has thousands of sensors on many technologies (machines) that generate data in real time. Modern manufacturing technologies supported by cloud computing and IIoT solutions already need engineers with the following skills: process and analyse data, understanding the processes from which data comes, understanding the processes of outputting visual data, understanding decision-making algorithms, mathematical and statistical knowledge that is needed to evaluate models at the prototyping stage, predictive maintenance, process optimization [35].

In the ongoing revolution, digital competences are a package of related competences, at the centre of which are digital technical competences supported by social skills (leadership, problem solving), interpersonal skills (cooperation, communication between people, teamwork), intrapersonal skills (self-discipline, lifelong learning, perseverance, self-motivation, critical thinking), proactive attitudes, and others. It is not possible to clearly indicate which digital competences are indicated as appropriate, because we use them for different purposes (e.g., learning, work, communication), and the conditions of their use have different frameworks (legal, professional, social, etc.).

According to an OECD survey, around 22 % of workers report that their qualifications are higher than what their current job requires, while 13 % of workers are underqualified. The Competence 4.0 project outlined 10 priority sectors of the economy: Electromobility, Energy, Industrial chemistry, Information and communication technology, Creative industry with a focus on the digital industry, Logistics with a focus on storage, Mechatronics, Modern industrial production, Food industry, Construction and Wholesale, Retail and e-commerce. For more than a year, experts from companies, research organizations, secondary schools and universities gradually mapped and described new trends and necessary competencies in innovative working groups.

An important tool for describing skills is the Competence Pyramid, which represent a hierarchical and systematically sorted summary of competencies in a given sector. The use of Competence Pyramids makes it possible to organize general and professional competences (knowledge and skills) from basics to narrow specializations. OECD states that over 45 % of jobs in the Czech Republic will disappear or change significantly over the next 20 years due to Industry 4.0.

3. Materials and Methods

This paper was developed based on an analysis of engineering education programs in the field of Industrial Informatics at technical universities in the Czech Republic and Poland. The research began with a detailed analysis of the scope of education at all universities offering technical education in Czechia. Universities that provide educational programs meeting the requirements of Industry 4.0 has been identified. These findings were determined through an analysis of the study field offerings available on universities websites. A similar procedure was used to review educational programs at technical universities in Poland.

The result of the analysis shows that the remaining universities currently do not offer educational programs identified as “Industry 4.0.” Even though the analysed universities implemented programs in automation and robotics, as well as programming, these did not meet the requirements defined by the authors for competencies of an “Engineer 4.0.” This includes the broad spectrum of collaboration between engineers and Industry 4.0 technologies, as well as roles performed in future enterprises (their potential workplaces).

Drawing on the principles of the Industry 4.0, the authors identified key areas of digital competencies for engineers in Industrial Informatics and may serve as a foundation for introducing changes to the educational programs in the field of Industrial Informatics.

4. Results

This chapter first describes the current state of teaching industrial informatics at universities in the Czech Republic and Poland, including case studies. Based on the analysis and analysis of graduate requirements, recommendations are formulated for teaching the study field preparing specialists for Industry 4.0.

4.1. Current States of Industrial Informatics at Universities in Czech Republic and Poland

At present, teaching concepts must be adapted to the evolving needs of society. In the era of the Internet and mobile digital technologies, where information that was previously inaccessible is now instantly available, the traditional educational structure based on the “lecture–exercise” model is becoming increasingly inadequate. The conference paper [36] refers to “the increasing importance of social media for teaching”. The paper [37] points out “the practical use of Facebook for universities, where the multiplier effects of this social network were activated by cooperation between teachers and students”. The paper [38] describes “the perspectives of IT/ICT students regarding their future jobs and the link between their learning outcomes and current employment”. In [39] “the requirements of small and medium companies for ICT professionals’ knowledge” has been analyzed.

A problematic element in the study of IT fields at Czech universities is the insufficient emphasis placed on databases technologies. Many academics in Czech universities consider databases to be of secondary importance and believe they lack sufficient “scientific” potential. This opinion is especially prevalent among those without practical experience in designing information systems. After graduating from university and entering the practice, students are often surprised to find that database applications and data processing are the common applications [40].

An innovative teaching approach has been applied at VSB – Technical University of Ostrava (Czech Republic). For over 15 years, programming has been taught using the robotic kit Bioloid (from the Korean manufacturer Robotis). According to [41] “robots created from the modular Robotis kit are excellent tools for teaching basic programming structures and explaining how to integrate hardware and software”. The Bioloid robots can also be used in teaching mathematics to clarify higher mathematical concepts (such as integrals or derivatives), and to demonstrate “how theoretical knowledge of mathematics can be applied in practice” [42].

In the recent years, there has been a growing tendency to integrate digital technologies into education, including the use of multimedia tools, video lectures, and recordings of laboratory experiments. Consequently, there is a demand to complement the teaching of technical subjects by videoconference, multimedia teaching materials and providing remote on-line lessons. But even “the use of multimedia has its limitations and cannot entirely replace the direct contact of teachers and students” [43].

The book [44] also presents the results of a study comparing the outcomes of teaching in two classes: “In the first class, teaching was conducted traditionally, using printed literature, while in the second class, teaching was conducted using tablets and multimedia teaching materials. The results of the second class gradually deteriorated”. This decline is attributed to the lower concentration of students when studying with multimedia materials.

In the Czech Republic, for almost four years (from 1/1/2019 to 12/31/2022), the project of the Ministry of Labour and Social Affairs, Competence 4.0 [45], mapped the trends of the 4th industrial revolution and their practical impact, influence on the labor market and education. Its goal was to identify the newly required skills and propose specific procedures that can then be quickly applied to the educational process.

4.2. Industrial Informatics in Study Fields: The Czech Republic and Poland

The following section describes existing study programs at universities in the Czech Republic and Poland that focus on processes and technologies related to industrial informatics and the concept of Industry 4.0.

4.2.1. Case study: The Czech Republic

Table 1 provides an overview of study fields related to Industry 4.0, currently taught at universities in the Czech Republic.

Table 1. Study fields related to Industry 4.0 at universities in the Czech Republic

University/ College	Bachelor/ Master	Name of study field	Comments
CTU (ČVUT), Faculty of machinery	Both	Bachelor: – specialization “Production technology and Industry 4.0”, Master: specialization in Robotics or Production Technology	It has been taught since 2016/2017
VŠB – Technical University Ostrava, Faculty of Electrotechnics and Informatics	Bachelor	“Computer systems for industry in 21st century”	In Czech: “Počítačové systémy pro průmysl 21. století”
VŠB – Technical University Ostrava, Faculty of Electrotechnics and Informatics (FEI)	Master	Study field “Industry 4.0”	
Tomas Bata University in Zlín; Faculty of Applied Informatics	Master	Study field “Automatic Control and Informatics in Industry 4.0”	
Škoda Auto University	Bachelor	“Industrial Management” study field	“Industry 4.0 Specialist” certificate
VUT Brno	Master	“Applied Computer Science and Control”	
ZČU Plzeň	Master	Smart manufacturing systems	Specialization: Manufacturing Machines and Technologies / Digital Manufacturing

The following specific subjects are taught at CTU (Czech Technical University in Prague) as part of the Industry 4.0 study field: Additive and alternative technologies, Knowledge and data engineering, Software engineering, Distributed systems, Computer vision and virtual reality, Law, security and intellectual property, or Human resource management.

At VŠB - Technical University Ostrava, the study field Industry 4.0 is a new and perspective field that combines the fields of informatics and cybernetics into a unique whole. Students of the field will learn about new trends in digitization and optimization of production. The ratio of practical and theoretical knowledge is balanced so that graduates are able to work actively within production plants and participate in and propose new methods for optimizing production processes.

As part of the diploma thesis, it is possible to solve tasks related to robot programming, predictive maintenance, quality detection using image analysis, etc.

Study field “Automatic Control and Informatics in Industry 4.0” at Tomas Bata University in Zlín is profiled by the following subjects: Automatic Control Theory, Sensors, Microcomputers and PLCs, Microelectronics, Real Process Control, Programming, Control System Design, Computer Network Operations, Numerical Systems Diagnostics, Robotics and Industry 4.0.

Škoda Auto University is a private university founded in 2000 by the largest car manufacturer in the Czech Republic, Škoda Auto a. s. Students of the Industrial Management bachelor's study field can obtain the “Industry 4.0 Specialist” certificate.

It is the first private university in the Czech Republic to receive institutional accreditation.

As a case study, there is a composition of compulsory and optional of subjects for obtaining the “Industry 4.0 Specialist” certificate in Table 1, Table 2, Table 3, and Table 4.

Table 2. Compulsory subjects

Subject in Czech	Subject in English
Technické předměty studijního programu Průmyslový management	Technical subjects of the study field Industrial Management
Nauka o materiálu	Material science
Konstruování	Construction
Strojírenská výroba	Engineering
Elektrotechnika	Electrotechnics
Části strojů	Machine parts
Automatické řízení	Automatic control
Automobilová technika	Automotive technology

Elective technical subjects are listed in Table 3. Students choose at least two subjects.

Table 3. Subjects with a technical theme that the student can take optionally

Subject in Czech	Subject in English
Virtuální realita	Virtual Reality
Základy 3D tisku	Basics of 3D printing
Programování robotů	Robot Programming
Plánování výroby v automobilovém průmyslu	Production planning in the automotive industry (subject taught by Škoda Auto a.s. managers)
Programování logických řídicích systémů	Programming logic control systems
Nové trendy v automobilovém průmyslu	New trends in the automotive industry

Table 4 lists the optional subjects in the field of IT/ICT, from which students choose at least two.

Table 4. Subjects from the field of IT that the student can take optionally

Subject in Czech	Subject in English
Technická infrastruktura a síťové technologie	Technical infrastructure and network technology
Řízení podnikové informatiky	Management of IT/ICT in corporation
Bezpečnost podnikání a ochrana dat	Business Security and Data Protection
Základy procesního řízení	Basics of process management
Algoritmizace a programování	Algorithmizing and programming
Datová analýza a databáze	Data Analysis and Databases
Numerické metody	Numerical Methods

At VUT Brno in the study field Applied Computer Science and Control, the subjects are arranged in the following scope: Mechanical Engineering, Technology and Materials (55 %), Informatics (25 %) and Electrical Engineering (20 %). VUT and CTU Prague have prepared a joint doctoral study programme in which the faculties and research centres of the two largest Czech technical universities will participate. It will be aimed primarily at applicants directly from industry, and the lectures will be conducted in English.

4.2.2. Case study: Poland

In the Polish education system, more and more IT educational courses have appeared at universities. Since the emergence of Industry 4.0, the popularity of educating engineers 4.0, including graduates of computer science with a focus on production, has been growing. Candidates are therefore expected to have, among other things, knowledge of Industry 4.0 technologies, thanks to which it is possible to use more flexible methods based on access to more information (e.g., CBM – Condition Based Monitoring). For companies that emphasize the implementation and management of systems based on Industry 4.0, it is also important for the employee to have experience in implementing modern solutions in the field of process automation, process and device integration, deepening automation using cloud computing technology and 3D printing.

The first field of education called Industrial Informatics at a technical university in Poland was reported to the education system run by the Ministry of Science on October 1, 2014 by the Silesian University of Technology. Up to now, according to the government website [46], there were five public universities with Industrial Informatics fields of study in the Polish gov. system, including 4 technical universities (as of April 10, 2024). The Industrial Informatics field of study is in the education profile called “general academic” or “practical”, see the list in Table 5.

Table 5. List of industrial informatics study field in Poland

University status		Level of studies		Education profile		Form of studies	
Public	5	First-cycle engineering studies	5	General academic	3	Full-time	5
Non-public	0	Second-cycle studies	1	Practical	3	Part-time	1

Source: [47]

Additional information: Studies in Industrial Computer Science are engineering or master's studies, the study field of which usually lasts from 3.5 to 4 years (first-cycle studies) or 1.5 years (second-cycle studies) and ends with obtaining a diploma (engineer or master of engineering).

Industrial Informatics is a response to the market demand for specialists in the design, operation, maintenance, and service of industrial information systems. How does Industrial Informatics differ from standard 'Computer science'? Initially, these are studies during which the emphasis is on the design of devices and systems of computer science and industrial automation. Additionally, programming and operation of industrial information systems are taught. An example would be the design of artificial intelligence programmes, database systems or multimedia systems. Popular specializations in Industrial Informatics are computer programming, services of technological processes, security of information systems.

The graduate should have knowledge and skills in the field of implementation, and operation of digital systems and devices, automation systems, principles of construction of modern computers and devices cooperating with them, operating systems, real-time operating systems, computer networks and databases, Artificial Intelligence, computer graphics and human-computer communication, design of operating systems, databases, computer networks.

Engineers after the Industrial Informatics can be employed as: IT systems analyst, programmer, industrial IT system operator, IT project manager, production specialist. If education is extensive at a given university, they can also be designers of intelligent field devices, PLC controllers, SCADA and DCS systems, databases or computer networks. In the basic engineering profile, the scope of education focuses on learning about industrial process support systems (production and logistics). The educational grids of universities are dominated by subjects of general engineering education and basic computer science as the basics of electrical engineering, electronics and measurement, basics of standardization and innovation, mathematical analysis, programming in "C", technical physics, internet applications, operating systems, advanced information technologies, introduction to rapid prototyping, theory of algorithms and data structures, basics of nanotechnology, general mechanics, programming of logistics processes in industry, strength of materials, thermal and flow installations, basics of automation, advanced technologies in machine construction.

4.3. Key Areas of Digital Competences for Engineer of Industrial Informatics

When studying the technologies crucial for the Industry 4.0, three distinct areas of competences can be identified (Figure 1). Every group has emphasized of different necessary skills.

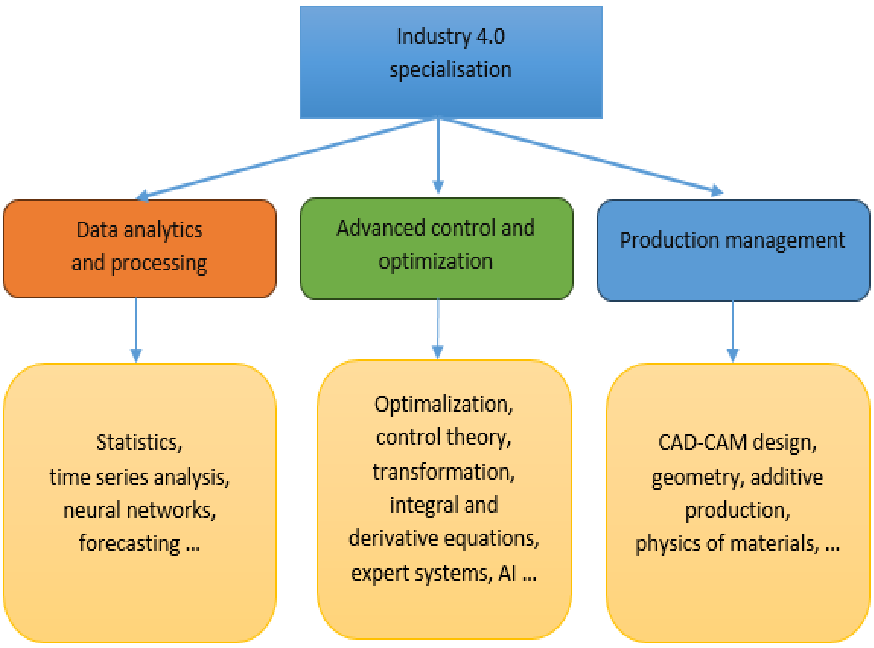

Figure 1. Areas of competencies in Industry 4.0.

The first area solves production data analysis and processing, and key skills include mastering data science. It means data analysis using statistics methods, OLAP analysis, neural networks, vector databases, big data technology and analytics, machine learning, machine vision, analysis of time series-oriented data (e.g., data collected from sensors) to allow calculating trends or forecasting. This direction is less technically oriented and rather requires competence in the field of statistics and mathematical analysis.

Second area covers all production control and optimization task. Employee should be familiar with control theory, identification, static and dynamic optimization, programming of robots, control loops, sensors data processing, expert systems and artificial intelligence. It is required good skill on integral and derivative equations, numerical computation, gradients and using several types of transformations (Fourier, LaPlace and others). This area requires extensive knowledge of numerical mathematics and solving algorithms. Digital competences and knowledge in the field of embedded systems is also important in this part.

Last area is focused directly on production and covers chain from design tools (from CAD to CAM) through production (additive production using 3D print). There are different skills required – spatial geometry, but also knowledge about materials, technological processes etc. This area is more technically oriented, only IT knowledge is not enough, but a good orientation in technologies, materials and construction is necessary. This direction is also connected with the technical means of automation and robotization.

When creating curricula for the accreditation of study fields, it is therefore necessary to consider which of these three areas (specialization) will be relevant.

The data about study programmes focused on Industry 4.0 at universities in the Czech Republic shows that these programmes are mainly implemented in technological faculties (mechanical engineering or electrical engineering). It is a natural development innovating the current fields of teaching automation and robotics. For that reason, study programmes are focused more on the third area (“Production”) listed in Figure 1. Fields of study that would primarily focus on the area of advanced production control and production data analytics are still lacking.

Based on analysis (Section 2 and Section 3) of universities study fields for students at the Industrial Informatics, the list of key subjects is proposed (Table 6).

Table 6. Key list of subjects for students at the Industrial Informatics

Subjects on bachelor level (common for all specializations)		
Selected topics from mathematics		
Selected topic from physics		
Management of corporation business processes		
Introduction to production control and management		
Logistics and product identification		
Statistic block		
Intelligent information and communication technologies		
Databases and big data technology		
Block of soft skills subjects		
Project management		
Corporate information systems		
Communication and networking		
Internet of things		
System integration		
Introduction to corporate financial management		
Control theory and automation		
Introduction to expert systems and AI		
Security of computer systems		
Subject on master level with specializations		
Spec: Data Analytics	**Spec: Advanced control**	**Spec: Production**
Statistics	Numerical mathematics	Materials and energy
Neural network	Transformations	Physics of materials and electrotechnics
BI and OLAP analysis	Decision and expert systems	Spatial geometry
Methods of Data Mining	Advanced control theory	Machinery for production and technologies of Industry 4.0
Time series analysis	Algorithms	CAD and design
Expert systems	Process monitoring and visualization	CAM and CNC
Forecasting/predictive analysis	Programming of robots	Sensors and buses, actuators
Big data analytics	Embedded systems programming	AI tools for design and forecasting
Cybersecurity	Static control	Robotics
AI tools for data analysis	Dynamic process optimization	Programming of robots
Vector databases	Application of AI tools	3D print and additive manufacturing
	Technological processes modelling	Digital twin and production modelling
	Virtual and augmented reality	Virtual and augmented reality

Note, Table 6 provides a concept and only selected topical subjects (or block of subjects) are listed.

5. Discussion

Modern education needs to adapt to social and technological changes, especially in an age of ubiquitous internet, mobile access, and the rise of AI tools. Traditional learning structures such as lectures and tutorials are increasingly seen as obsolete when students can access information online. For example, the integration of social media into the classroom has proven effective in increasing engagement, as seen in the use of platforms such as Facebook for collaborative learning and project management. However, the importance of direct teacher-student interaction remains considerable, as multimedia tools and digital teaching methods can have limitations. Research by [44] found that students who used multimedia learning materials experienced a decline in learning outcomes compared to those who relied on traditional print resources, highlighting the need for balanced learning approaches.

The competencies should aim at synergy between soft skills and hard skills so that there is collaboration between technical staff, economic and economic-managerial and social fields. In doing so, these participants should have the ability to anticipate challenges and possible solutions themselves. These interdisciplinary collaborations "foster creativity based on different expertise, and their group creative thinking allows them to bring new innovative ideas and ideas for the organization and the customer" [48]. Linking soft skills with the required technical and digital know-how is already essential in the labor market [49], [50].

In the last few years, a major technological trend becomes the rapid development of the use of AI tools for almost every field. Knowledge and ability to use artificial intelligence tools will be key for students to succeed in technological fields. These tools will replace routine work (such as creating program code), but human control over the results will still be necessary. A shift is expected from learning facts to teaching critical thinking and managing tasks with a higher level of complexity.

6. Conclusion

With the development of society and digitalization of production according the ideas of Industry 4.0, it is necessary to deal with education and the implementation new elements in all study plans, as the requirements for graduates' change, and the development of AI moves rapidly.

Universities must change the fields of education to educate for new professions or professions of the future. Those related to data analysis will certainly be necessary, although they will also evolve towards very specific specializations, e.g., significant data analyst, decision information analyst, data graph analyst, data risk analyst, organization cost analyst, sales analyst, profile analyst client etc. Universities are trying to respond to signals from the environment and are slowly implementing student education in new fields (in the next few or a dozen years). Transformation of the production will cause changes in the required professions composition and increase demand for specialists with special competencies.

The process of introducing new study fields at universities is relatively slow, and in the near future it may happen that the qualifications of technical workers will not be in line with technological changes. As it emerged from the analysis, schools are currently directing innovation in the area of production and, to a lesser extent, in data analysis. Advanced control of technological processes is essentially neglected. It is also important, if the will is to solve problems ahead of time, to pay attention to the motivation of high school youth toward studying modern technical disciplines.

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