INDUSTRY 5.0. OR INDUSTRY 4.2

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Abstract: Industry 5.0 represents a significant evolution in industrial development, building upon the technological foundations of Industry 4.0. Highlighting human-centric and sustainable approaches, Industry 5.0 aims to integrate human creativity and technology seamlessly. While previous industrial revolutions were marked by technological advancements—such as steam engines, electricity, and digital transformation—Industry 5.0 emphasizes the synergy between humans and machines. This collaboration is expected to drive production efficiency and ethical practices in industry, creating a more resilient and human-focused future. This paper investigate the needs to education systems to prepare the students to i5.0.

Keywords: *industry 5.0, industry 4.0, sustainability, collaborative robots (cobots), AI, autonom vehicles, human-machine interactions*

1. INTRODUCTION

The term Industry 5.0 was adopted by the European Commission in its white paper Industry 5.0 - Towards a sustainable, human-centric and resilient industry, published in January 2021.

According to the scientific approach, previous industrial revolutions were provoked by the introduction of one or more new technologies, each of which brought about a radical paradigm shift in industrial production. Accordingly, however, the described elements of industry 5.0 are based on the same core technologies as industry 4.0. Therefore, it should rather be seen as a complementary concept to Industry 4.0.

The most significant distinction between Industry 5.0 and its predecessors is its emphasis on the human element.

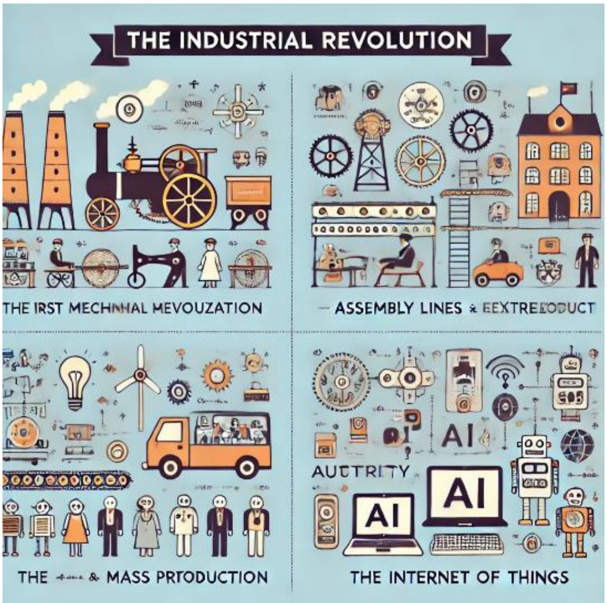

Figure 1 The first four industrial revolutions

The four industrial revolutions shown in Figure 1 can be described as follows:

- The first industrial revolution (late 18th century):
    - Characterised by the appearance of steam engines and textile machinery. This era began with the transformation of manual production into machine production, with the steam engine at its heart. Agricultural societies became industrial societies.
- Second industrial revolution (late 19th century - early 20th century):
    - Characterised by electricity and the spread of mass production. Assembly lines, electricity and new materials (e.g. steel) revolutionised manufacturing, enabling large-scale production.
- Third industrial revolution (mid to late 20th century):
    - Created by the arrival of computers, automation and information technology. More and more processes in industry were automated and computer-controlled machines appeared, increasing efficiency.
- Fourth industrial revolution (21st century):
    - Characterised by digital transformation, artificial intelligence (AI), robotics and the Internet of Things (IoT). Integration of smart technologies, automation at a higher level and

acceleration of industrial production's entry into the digital world.

These industrial revolutions led to significant social and economic changes.

Industry 5.0 is a new stage of development that follows the digital revolution of Industry 4.0. While Industry 4.0 is based on automation, robotics and the Internet of Things (IoT), Industry 5.0 aims to create harmony between people and technology, emphasising human creativity and value. Human-machine collaboration will take production to a new level, bringing technology and ethics to the forefront [1].

2. KEY FEATURES OF INDUSTRY 5.0:

- Human-machine collaboration: Industry 5.0 aims to take human-robot collaboration to a higher level, where machines support, but do not replace, humans. The focus is on the creativity and problem-solving abilities of humans, while machines perform repetitive, monotonous tasks.
- Custom production: in the era of Industry 5.0, the focus will be on the production of individual, customised products.
- Sustainability. The focus of technology is on reducing environmental pressures and using resources more efficiently.
- People-centric: People are at the centre, not only as employees but also as individuals who contribute to the production process based on their personal values and skills.

Industry 5.0 therefore envisions a future where technology does not replace people, but supports them, enhancing innovation and sustainability.

The theory of Industry 5.0 is already being manifested in practical applications. Some examples are presented in relation to the four main characteristics:

- Human-machine interaction:
  - Cobots: Companies such as Universal Robots and Kassow Robots are developing collaborative robots (cobots) that work directly with humans on production lines. These robots can safely manage complex tasks in close proximity to humans, such as precision assembly (Figure 2).

    - BMW production lines: cobots are used in BMW's car factories to carry out heavy lifting and repetitive tasks, while human workers concentrate on more sophisticated, highly demanding jobs [2].
- Customized production:
    - Nike and Adidas - custom shoe production: Nike and Adidas have introduced systems that allow customers to design custom shoes, which the companies quickly produce to order. Automated systems help to provide the flexibility of mass production while tailoring products to individual needs [3].
    - 3D printing: General Electric is using 3D printing in the aerospace industry to produce custom parts, reducing production time and costs. 3D printing allows for customized solutions in manufacturing.
- Sustainability:
    - Siemens - smart energy systems Siemens has developed smart grid solutions that optimise energy production and distribution, enabling sustainable energy management in factories. Smart systems help to improve the energy efficiency of manufacturing processes and reduce emissions.
    - Tesla Giga Factory: the Tesla Giga Factory is fully based on renewable energy sources, and the batteries produced there will help the uptake of electric vehicles, which will reduce the use of fossil fuels in the long term [4].
- Human centricity:
    - Toyota - Lean Manufacturing Philosophy: Toyota's manufacturing system, which is based on the development of human workforce and continuous improvement (Kaizen), can be seen as a forerunner of Industry 5.0. Here, workers play a major role in optimising production processes and the company places a strong emphasis on the use of human capabilities.
    - Ericsson - developing human capabilities: some of Ericsson's industrial projects in the telecommunications sector focus on developing human creativity and problem-solving capabilities, particularly in innovative approaches to the development and use of technology.

Figure 2 Cobot works in Ceske Budejovice

These industrial examples show that the Industry 5.0 process is already here, supporting the human-centred development of technology alongside sustainability and customisation.

Autonomous vehicles are a typical manifestation of Industry 5.0. Here, the human instructs, but the machine, car, on the basis of current measurement data and Internet sources, chooses the direction and achieves the desired destination [5], [6], [7], [8].

Another increasingly used area of Industry 5.0 is the additive manufacturing technology, which can produce any kind of geometric shape, even bionic or organic, through generative design supported by artificial intelligence [9], [10]. With this manufacturing technology, even in an office environment, we can produce one-at-a-time customised parts without designing and manufacturing tools.

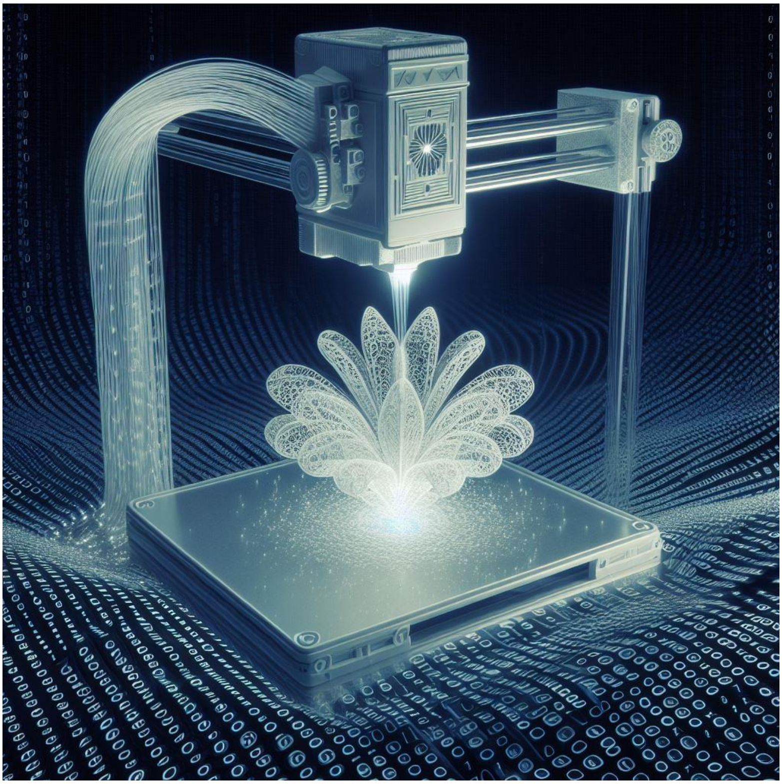

Figure 3 Figure about a 3D printer works from data from cloud made by copilot

This is a perfect example of customised, sustainable manufacturing, while maintaining the human-machine relationship, where humans are assigned higher-level design and production planning tasks. In such tasks, for example, production parameters and settings can have a significant influence on the final result, on the product [11], [12], [22].

3. THE EXPECTED ADVANTAGES AND DISADVANTAGES OF IMPLEMENTING INDUSTRY 5.0

Implementing Industry 5.0 can be beneficial in many ways, but it also brings challenges and difficulties.

- Advanteges:
  - Harnessing human creativity: one of the key benefits of Industry 5.0 is that it highlights the creativity and problem-solving skills of the human workforce, while machines take

over repetitive tasks. This increases job satisfaction by allowing workers to focus on more valuable, innovative tasks.
  - Tailored production: Consumers are increasingly demanding personalised products. Industry 5.0 makes manufacturing processes flexible, allowing for customised production while maintaining the efficiency of mass production. This can increase competitiveness and market share.
  - Sustainability and green technologies: Sustainability is at the heart of Industry 5.0. Smart energy use, green technologies and resource optimisation can reduce environmental impact. This will make industrial processes not only more economically efficient, but also more environmentally friendly.
  - Increased competitive advantage: Collaboration between machines and people, integration of digital technologies and automation will increase productivity. Companies can respond more quickly and efficiently to changing market conditions, while introducing new, innovative products and services.
  - Better working environment: A human-centred approach can improve the working environment and make people feel safer. Cobots can help perform accident-prone or tiring tasks, reducing workplace stress and improving employee well-being.
- Disadvantages and difficulties:
  - High start-up costs: implementing Industry 5.0 can require significant investment, especially for new technologies such as robotics, artificial intelligence, IoT and the deployment of digital systems. This can be a challenge for smaller companies, as initial capital requirements can be high.
  - Reskilling the workforce: Industry 5.0 requires new skills, particularly in digital technologies and automation. Workers need to be retrained to interact with robots and use new systems. This is not only time-consuming and costly, but can also create resistance among workers.
  - Technology dependency: Industry's heavy reliance on 5.0 technology also brings with it the risk of system disruption. If automated systems malfunction or fail, it can cause severe production downtime, impacting productivity and company revenues.
  - Data protection and cybersecurity: the increasing use of digital technologies also brings cybersecurity risks. Data protection

compliance and the protection of sensitive data will be critical, especially for IoT and AI systems. Addressing cybersecurity challenges can add cost and complexity.
    - Social and labour market impacts: Although Industry 5.0 relies on the interaction between human labour and technology, automation may lead to job losses. This may particularly affect low-skilled workers, who risk being excluded from the labour market.

Industry 5.0 offers many advantages, especially in terms of customised production, sustainability and leveraging human creativity. However, high deployment costs, technological dependency and retraining of the workforce can pose challenges. Nevertheless, this direction of industrial development is likely to be essential for future competitiveness and sustainability.

It should be noted that most of the disadvantages listed here are already present in the implementation of Industry 4.0, so they would not pose additional difficulties and challenges in moving on from it.

4. INDUSTRY 5.0 IMPLEMENTATION REQUIREMENTS

The introduction of Industry 5.0 requires extensive preparation by industrial companies and society. A number of technological, economic and human factors are prerequisites without which the effective implementation of Industry 5.0 cannot be achieved.

- Prerequisites:
    - Advanced technology infrastructure:
        - Artificial intelligence (AI) and machine learning: in Industry 5.0, machines not only perform automatic processes, but can also learn from databases. Advanced AI systems are therefore needed to support the optimisation of manufacturing processes and collaboration with robots.
        - IoT (Internet of Things). Stable, fast data connections are needed to link production lines, sensors, robots and other systems.
        - 5G network: A high-speed, low-latency 5G network is essential for real-time data processing and communication between devices connected to the network. 5G will ensure continuous connectivity of production systems and fast data transfer.

    - Cloud-based systems and computing. Cloud computing enables companies to access data quickly, optimising production and inventory management.
- Reskilling and upskilling of human resources:
    - To implement Industry 5.0, workers need new skills, particularly in digital technologies, robotics and data processing. Companies need to invest in reskilling their employees to enable people to work effectively with collaborative robots (cobots) and other intelligent systems.
    - Soft skills. Industry 5.0 requires a creative, problem-solving mindset and a willingness to innovate. Educating people is not only necessary for technical skills, but also for teamwork, creative thinking and adapting to change.

- Organizational change:
    - In order to ensure the successful implementation of Industry 5.0, it is essential that companies adapt their approach to align with the key principles of collaboration between people and machines, flexibility and innovation. This necessitates a transformation of corporate hierarchies and the adoption of novel technologies.
    - Agile operations: Industry 5.0 implies a dynamic and fast-changing environment, so companies need to be able to react quickly to market changes, new technologies and customised production needs. Agile operating models facilitate adaptability.
- Commitment to sustainability:
    - Industry 5.0 emphasises environmental sustainability. Companies should invest in technologies and solutions that reduce energy consumption, minimise waste and enable more efficient use of resources.
    - Circular economy: production is based on the principles of the circular economy, with a focus on recycling of raw materials, energy saving and environmental protection. The pursuit of sustainability is a fundamental expectation in the era of Industry 5.0.
- Data security and cybersecurity:

        - With the rise of data-driven manufacturing systems, data protection and cyber security are becoming increasingly important. Companies need to establish strict data protection policies and implement strong security systems to protect their systems from cyber-attacks (NIS2).
        - Data protection: the proper handling and protection of the huge amount of data generated during production is essential, especially for sensitive business or customer data.
    - Economic and government support:
        - The implementation of Industry 5.0 will require significant investment, so it is important that companies have access to government subsidies, incentive programmes and access to credit facilities. Governments have a key role to play in promoting technological progress.
        - Regulatory environment: The right legislative and regulatory framework is needed to ensure that technological developments can be smoothly introduced. This includes digital legislation, data protection regulations and cybersecurity protocols.

In summary, the implementation of Industry 5.0 requires advanced technology systems, a skilled workforce, organisational culture change and cybersecurity measures. The pursuit of a harmonic interaction between man and machine, as well as sustainability and innovation, is essential for the successful deployment of this new era of industry.

Since the application of AI has already appeared in the field of industry4.0 and is also a pillar of industry 5.0, it is important to mention its applicability and legal background. Currently, this is a grey area, there are regulatory initiatives, but at global level the legal standards for the application and adoption of AI are not clear. The AI Act, which will enter into force on 1 August 2024, would help to address this, but would only regulate its applicability in the EU. While this is useful in many cases (life protection, health decisions, etc.), it also involves serious risks. However, the result of a ban in critical areas could in some cases be a significant competitive disadvantage [14].

5. CHANGES IN VOCATIONAL EDUCATION AND HIGHER EDUCATION AS A RESULT OF INDUSTRY 5.0

Industry 5.0 brings new challenges and opportunities for vocational education and universities, as the needs of the job market are dramatically changing due to technological developments. The education system needs to adapt to this, so that the workers of the future can take advantage of the opportunities for human-machine interaction and meet the demands for sustainability, innovation and creativity.

5.1. Interdisciplinary and flexible education programmes

- Industry 5.0 requires employees to be multidisciplinary. Educational institutions need to place greater emphasis on developing interdisciplinary courses that combine engineering, IT, management and human skills.
- Integrating engineering, IT and robotics with creative thinking or sustainability skills will be key [15], [16].

5.2. Develop digital skills

- Digital technologies such as AI, IoT, robotics, and data management are essential elements of Industry 5.0, so it is important for both vocational training and higher education to provide comprehensive digital literacy education.
- The education of programming, data processing, AI development and cybersecurity will play a key role in the education structure of Industry 5.0.
- The introduction of AI-based systems and the Internet of Things (IoT) in automotive and engineering systems requires engineers to be able to connect and code the different components of these systems.
- Self-driving cars and predictive maintenance require AI technologies that enable engineers to optimise the performance of vehicles and the efficiency of manufacturing systems [17].

5.3. Developing soft skills and creativity

- One of the key elements of Industry 5.0 is the focus on human creativity and innovation. Therefore, education systems need to put more emphasis on the development of soft skills (e.g. creative thinking, problem solving, teamwork, communication) as they play a key role in the collaboration between humans and robots.
- Training methods such as project-based learning, real-world problem solving and creative design (e.g. design thinking) will be an important part of the future education.

5.4. Supporting lifelong learning

- The rapid technological changes in Industry 5.0 mean that employees are constantly having to learn new skills, making Lifelong Learning essential. Vocational and higher education institutions must offer flexible, modular learning opportunities that employees can use at any point in their careers.
- The introduction of online training, micro-credentialing programmes, courses and reskilling programmes will make it easier for experts to learn new technologies [21].

5.5. Collaborative robots and robotics education

- Cobots (collaborative robots) are a key element of Industry 5.0, so both vocational and higher education are focusing on teaching how to work with robotics. The new generation of experts will need to know how to use cobots, how to program them and how to integrate them into production processes.
- For example, robotics, automation and maintenance of industrial systems, as well as artificial intelligence programming, are areas that will be essential in the future of the job market.

5.6. Sustainability and environmental skills

- Environmental sustainability and efficiency is a key requirement of Industry 5.0, so training should focus on teaching sustainable technologies and production processes. Knowledge that supports resource-efficient production and the

  - principles of a circular economy will be needed, taking into account environmental impacts [20].
  - Educational institutions should work closely with industrial partners to integrate sustainable methods and technologies into industrial practices.

5.7. Promoting creative and innovative thinking

Education should support the development of innovation skills and entrepreneurship, as Industry 5.0 builds on human values and creativity. Therefore, entrepreneurial skills, learning about start-up culture and focusing on creative thinking will help individuals to adapt to the changing industrial environment.

5.8. Stronger links with the job market and industry

  - The impact of Industry 5.0 will bring even closer cooperation between educational institutions and the labour market. Joint industry-education projects, internships and close cooperation with industry partners will give students the opportunity to meet real industrial problems and gain practical knowledge.
  - Training programmes developed with industrial partners help to ensure that education responds directly to the needs of the job market.

In the era of Industry 5.0, mechanical and automotive engineers will need new competences and mindsets in addition to traditional engineering skills.

With the emergence of Industry 5.0, digital skills, knowledge of automated systems and AI technologies, and creative, sustainability-oriented thinking are essential for newly qualified mechanical and automotive engineers. A systemic approach, open-mindedness to human-machine collaboration and a commitment to lifelong learning will ensure that engineers successfully respond to the new industrial requirements.

Newly qualified engineers need a broader knowledge base and a more analytical mindset to successfully implement Industry 5.0. Industry 5.0 will build on a combination of digitalisation, artificial intelligence and personalised production processes, requiring a high level of multidisciplinary knowledge and flexible thinking.

Therefore, Education and vocational training should also focus on these areas to ensure that future engineers are prepared for the challenges of Industry 5.0.

6. INDUSTRY 5.0 OR INDUSTRY 4.2

According to some experts, Industry 5.0 is not so different from another technological revolution, but a new way of thinking, focusing on the sustainable use of people and technology, with the help of digital twins and augmented reality (AR) [18], [19].

The perception of Industry 5.0 as an industrial revolution in its own right or as an extension of the fourth industrial revolution (Industry 4.0) is often debated. Some features of Industry 5.0 overlap with Industry 4.0, but there are also clear differences. The arguments for both perspectives are presented below:

6.1. Industry 5.0 as a separate industrial revolution

- People-centric: A key feature of Industry 5.0 is the emphasis on the human role alongside technological systems. While Industry 4.0 focuses on full automation and the development of machine intelligence, Industry 5.0 aims to optimise human-machine interaction. Collaborative robots (cobots), for example, work together with humans, bringing a new dimension to manufacturing and production.
- Sustainability and social responsibility: Industry 5.0 will focus on sustainability and social responsibility issues, which were less in focus in Industry 4.0. Energy efficiency, the circular economy and the integration of green technologies are key elements that will set a new direction for industrial development.

- Customization and tailor-made production: Industry 5.0 emphasizes customized products and services, while Industry 4.0 focuses on automated, high-volume, standardized production. New technologies (such as 3D printing) allow for greater flexibility and rapid adaptation to customer needs.
- Technology-human balance: Industry 5.0 aims to find a balance between smart technologies (e.g. artificial

intelligence, robotics) and human creativity and responsiveness. This differs from the goal of Industry 4.0, which sought to minimise human intervention through automation.

6.2. Industry 5.0 as an extension of Industry 4.0 (e.g. Industry 4.2)

- Technological continuity: The technological basis of Industry 5.0 (automation, artificial intelligence, IoT) is closely linked to the achievements of Industry 4.0. In fact, Industry 5.0 is essentially an evolution of Industry 4.0, where new goals and values are set, building on technological progress, but the starting point and the toolbox are the same.
- Common technological base: Both eras are built on technologies such as AI, Big Data, automation, and IoT. The difference mainly in the ways they are used, not in the new technological foundations. Therefore, many believe that Industry 5.0 is just another evolutionary phase in Industry 4.0.
- The human factor is also present in Industry 4.0: Although Industry 5.0 explicitly emphasises human-machine collaboration, Industry 4.0 already includes the role of human intervention in the monitoring and control of intelligent systems. Thus, many believe that Industry 5.0 is not a new industrial revolution, but a refinement and humanisation of Industry 4.0.
- Focus on flexibility and customisation: The possibility of customised production, which Industry 5.0 highlights, can also be realised with Industry 4.0 technologies. For example, 3D printing and mass customisation were also present during Industry 4.0.
- o According to several opinions, industry 4.0 frightened people, which is why a new name had to be given, emphasising the role of people

7. SUMMARY

Industry 5.0 can partly be seen as an extension of Industry 4.0, as the technological foundations are largely the same. However, the human-centred approach, the focus on sustainability and the emphasis on personalised production methods lead many to see Industry 5.0 as a new industrial revolution. Depending on whether you look at the technological or the social aspects, Industry 5.0 could be a continuation of Industry 4.0 or a new chapter in the history of manufacturing.

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