Educational methods for Industry 4.0

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Industry worldwide is facing new challenges, particularly the implementation of new technologies, climate change and currently the pandemic of the disease caused by the new coronavirus COVID-19. For the industry to be competitive, it must make technological changes. These changes are based on the concept of Industry 4.0. The changes brought about by implementing the Industry 4.0 concept and the related digitization of the economy have implications for the functioning of markets, industries, and other sectors. Significant impacts can be expected on the labor market when the demand for specific professions changes and new competencies will be required for employees. The fundamental question is how specifically these requirements can be implemented in current education conditions, specifically in the university environment. As part of practical training, it is unrealistic to demonstrate new ways of operation management on an extensive product line. It is very effective to use various forms of small-scale models. These models behave practically the same as in actual operation, and students can try out different production states, problem-solving and subsequent optimization. This article describes how we solve this problem in our university.

Industry 4.0, education, digitization, implementing, practical training, problem solving

I. INTRODUCTION

Industry, not only in the Czech Republic but also worldwide, is currently facing problems and challenges related to new technologies, climate change and the global pandemic caused by the new coronavirus SARS-CoV-2.

In 2011, the German government launched the Industry 4.0 strategy and proposed a transition from "centralized" to "decentralized" smart manufacturing, in which the world of manufacturing and networking will be brought together in the Internet of Things (Fig. 1). The strategy called for the creation of a smart industry in which people, devices, objects and systems come together to form dynamic, self-organizing production networks.

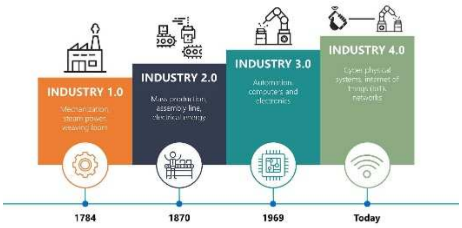

Fig. 1. Industrial revolutions [4]

II. THE CURRENT VIEW

For this reason, a new perspective on production is very important. In particular, the interconnection between machines, products, employees and suppliers is coming to the fore. This is made possible by the concept of Industry 4.0 and the technologies it brings with it. The key concept is digitalization. The future lies in so-called smart factories.

These highly digitized, interconnected production environments are controlled by smart production elements. One of the key elements of Industry 4.0 is a simulation and its digital twin, which are virtual models of the real (physical) system on which the current state and various situations that may occur during production are modeled.

The connected smart factory works as a single unit. It is equipped with modern machines and technologies, robots or cobots and a lot of sensors with communication via the Internet of Things (IoT). The production processes generate data that are stored in central repositories (Cloud, Edge Computing) and are processed there using advanced algorithms (Big Data), machine learning (ML) or artificial intelligence (AI). This data is further used in the digital factory model (Digital Twin) and can be extended to include virtual reality (VR) or augmented reality (AR) deployment. It is also possible to use NFC and RFID chips to transmit production information and parameters of goods to machines. These technologies and principles create an intelligent factory that is capable of autonomous control, using the evaluated data to efficiently propose optimizations and thus save material and time. Using machine learning, it is possible to predict failure easier and prepare for taking timely corrective action in advance.

III. COMPETENCES FOR THE 21ST CENTURY

Here it is also necessary to recall the often-mentioned notion of "competences for the 21st century". We need to recognize that the rapidly changing economic, cultural and social environment requires an adjustment of what we consider important (key) and the resulting knowledge that future generations should have. We must not forget creativity, critical thinking, curiosity, collaboration or innovation, including intercultural understanding.

The latest developments show the growing interdependence of social science and industrial advances with the overall design of education systems. The increasing implementation of artificial intelligence, robotics, but also the greater use of neural networks, implies that people will not engage in routine activities, but instead will use the aforementioned "competences for the 21st century", and will use critical thinking, emotional intelligence, creativity ... skills that artificial intelligence does not yet master. However, in order to focus on and further develop these competences, one must have a certain foundation. This foundation must be made available to him through the education system.

In connection with the idea of how to prepare today's students for the turbulent changes that contemporary society is undergoing, there is a need to adapt teaching. Even employers are beginning to complain that today's graduates are not sufficiently equipped with these competences and that the current education system is inadequate in this direction.

So, what steps should be taken to prepare students for these challenges? The first important step is certainly to develop more cooperation between universities and industry. Focus study programmes professionally, emphasizing practical skills, including compulsory internships. Another important step is to embed technology itself directly into teaching. Not only technologies to support teaching, but especially to introduce students to technologies that they can use in the implementation of Industry 4.0.

IV. NEW WAYS OFLEARNING

At our department, we try to be consistent with different approaches. We are working with the approach "Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution" to implement change [1]. This is a report by the "World Economic Forum" that describes what a school of the future should look like to prepare students for existence in the era of Industry 4.0. It is important to remember that many of today's children will be working in positions that do not yet exist, most of whom will need a simultaneous better understanding of digital technology and social-emotional skills. They will be working in entirely new business models, in a connected world, and will be expected to collaborate with colleagues from different parts of the world.

The report [1] describes two areas - learning objectives and learning activities, in other words, eight key characteristics of quality education for the needs of the fourth industrial revolution.

Learning objectives:

- Global citizenship skills: Include content that focuses on building awareness about the wider world, sustain-ability and playing an active role in the global community.
- Innovation and creativity skills: Include content that fosters skills required for innovation, including complex problem-solving, analytical thinking, creativity and systems analysis.
- Technology skills: Include content that is based on developing digital skills, including programming, digital responsibility and the use of technology.
- Interpersonal skills: Include content that focuses on interpersonal emotional intelligence, including empathy, cooperation, negotiation, leadership and social awareness.

Teaching activities:

- Personalized and self-paced learning: Move from a system where learning is standardized, to one based on the diverse individual needs of each learner, and flexible enough to enable each learner to progress at their own pace.
- Accessible and inclusive learning: Move from a system where learning is confined to those with access to school buildings to one in which everyone has access to learning and is therefore inclusive.
- Problem-based and collaborative learning: Move from process-based to project- and problem-based content delivery, requiring peer collaboration and more closely mirroring the future of work.
- Lifelong and student-driven learning: Move from a system where learning and skilling decrease over one’s lifespan to one where everyone continuously improves on existing skills and acquires new ones based on their individual needs

Another important document with which we would like to be aligned is the "Future of Education and Skills 2030" [2], which emerged from an OECD project. This project aims to develop the skills and values that students need to shape their future career paths. In order to illustrate this, the 'Learning Compass 2030' has been developed (Fig. 2), which in seven areas identifies the skills, knowledge, attitudes and values that are crucial to shaping students' futures.

Fig. 2. OECD – Learning Compass 2030 [2]

Like a compass that helps travelers find their way, the Learning Compass shows the knowledge, skills, attitudes and values that students need to cope with changes in our environment and everyday life and to help shape our future.

The Learning Compass consists of seven elements: [2]

- Core foundations - defines the basic conditions and foundational skills, knowledge, attitudes and values that are prerequisites for further learning in the curriculum, all students need this solid foundation to fulfill their potential to become the answer.
- Transformative competencies - to meet the challenges of the 21st century, students must be motivated and feel they can help shape the world.
- Student agency/co-agency - Student attitude is defined as the ability to set a goal, to think and

respond responsibly to change, and to make responsible decisions and choices rather than making decisions for others.

- Knowledge - Theoretical concepts and ideas are part of the learning process, in addition to theoretical understanding based on experience of performing certain tasks.
- Skills - Skills are the ability and capacity to carry out processes and be able to use one's knowledge responsibly to achieve a goal.
- Attitudes and values - Attitudes and values refer to the principles and beliefs that influence a person's choices, behaviors and actions; strengthening and rebuilding trust in institutions and among communities requires greater effort and development of core shared values.
- Anticipation-Action-Reflection cycle - An iterative learning process in which students continually improve their thinking and acting responsibly; in the anticipation phase, they learn how actions taken today may have consequences for the future.

How can we prepare students for jobs that have not yet been created, for solving societal challenges we cannot yet imagine, and for using technologies that have not yet been invented? Students need support in developing not only knowledge and skills, but also attitudes and values that can lead them to act ethically and responsibly. The present need opportunities to develop their creative ingenuity to help move humanity towards a brighter future. The competencies to do all this can be made possible by these new models of education.

The crucial question is how these requirements can be practically implemented in the conditions of contemporary Czech education, specifically in the environment of universities. Within our workplace, which is the Department of Materials and Technology of the Faculty of Electrical Engineering of the University of West Bohemia in Pilsen, we have set ourselves the goal of monitoring and incorporating these trends into teaching. In the current academic year, we have started teaching a new study programme "Materials and Technologies for Electrical Engineering", an important part of which is the focus on "Process Control". Within this focus, it is possible to get a deeper insight into the issues of technological process control, modelling and optimization, quality management tools, communication and control systems in industrial organization as well as systems engineering in electrical engineering. Everything is covered by the aforementioned Industry 4.0 concept.

It is unrealistic to demonstrate new management methods on a large production line in a practical training course. It is very effective to use various forms of scale models. These models behave practically the same way as a real plant and students can try out different production states, problem solving and subsequent optimization on them. In our department, we first started and using the popular LEGO building blocks. We prepared simulation games for practical testing especially inventory control, finding bottlenecks in production with emphasis on optimizing batch production. Afterwards, the students were able to try out lean manufacturing, just in time and just in sequence issues and the design of an optimal production line for the production of small off-road cars (Fig. 3).

Fig. 3. Using Lego building blocks in teaching

The changes brought about by the implementation of the Industry 4.0 concept and the related digitalization of the economy have implications not only for the functioning of markets and industries, but also for other sectors. Significant impacts can be expected on the job market, where the demand professions will change and employees will be required to have new competencies and skills referred to as "digital skills." This will therefore also have significant implications for education at all levels.

Before the beginning of the academic year, we made significant progress in the innovation of teaching towards technologies for Industry 4.0 and in support of the above-mentioned study programme, our department has purchased the Industry 4.0 Training Factory model (Fig. 4), supplied by the German company Fischertechnik. This model enables a faithful simulation of the production line and allows working with a scaled model as in the reality. On a small scale, it is possible to simulate many potential states (including failure states) and situations, learn how to manage them, as well as apply the newly acquired knowledge and then implement it on a large scale. It is possible to simulate the ordering, production and delivery processes. Every part of the line is (as in the future factories) interconnected with each other.

Fig. 4. Model Industry 4.0 – Training Factory [3]

The training model consists of several components:

- Storage and retrieval station
- Sorting line with color detection (blue, white, red)
- Multi-purpose station with furnace simulation
- Robotic conveyor (vacuum suction gripper)
- Rotating camera

- Environmental sensors (temperature, humidity, air pressure, air quality, light conditions)
- Traffic lights for factory status

The line is controlled by Fischertechnik TXT controllers (Fig. 5). Six of them are installed in this model, they are interconnected and communicate with each other via the MQTT protocol. MQTT (Message Queuing Telemetry Transport) is an open protocol that allows the transfer of the data between devices.

Fig. 5. Robotics TXT control unit [3]

After placing an order, the products pass through the relevant stations of the production line, while the current production status can be viewed on the control panel. A two-axis rotary camera monitors the entire production process and can also be used for remote monitoring of the production line. Individual products are tracked using NFC technology. Unique identification number (ID) is assigned to each product.The production stations must be connected to the Fischertechnik Cloud. The software application is written in C/C++. After connecting the interface to the model, the connection of the control units, the settings and the camera functions are checked and the current state of the model is read. Within the user views, it is possible to monitor the current status of the factory. It shows the factory status, production process, warehouse, NFC/RFID reader and sensor values and the camera monitoring the whole plant is controlled from it. All of these functions are controlled and switched via an on-screen menu (Fig. 6).

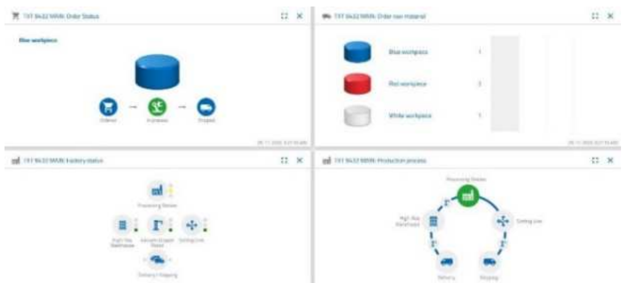

Fig. 6. The Dasboard can be viewed via computer or mobile devices

The current status of the modules is visualized by a traffic light. Green indicates that the module is active, orange indicates waiting for the next action. In the event of a fault or problem, the traffic light of the graphics of the module in question lights up red. The individual production steps/modules are converted into a simple diagram and displayed in the Production process window. The active node lights up green or red depending on whether the process step is functional or whether an error has occurred and is awaiting repair. In the Stock window, the current stock status is displayed, including the stocked items. This view is only used to visualize the stock. The last view is the NFC/RFID reader, where the workpiece data capture times are displayed and can also be deleted here.

During the practical training, students have the opportunity to make software modifications to individual production components. The control program can be modified in the ROBO Pro development environment, where it is possible to programme using individual blocks and their composition into flowcharts, or directly in the C/C++ language. A great advantage is that all programming libraries and APIs (Application Programming Interfaces) are published on Github (provider for internet hosting for software development) and can be used [3].

The aim of this teaching module is to practically show students the basic principles of the Industry 4.0 concept. To enable them to become familiar with new trends, apply new thinking based on decentralized management and develop communication skills within the solution team.

In teaching this new study programme, we are therefore in line with the The World Economic Forum (WEF) approach - "Schools of the Future: Defining New Models of Education for the Fourth Industrial Revolution" and also with the OECD project - "Future of Education and Skills 2030". We need to create new models of education that are in line with the needs of the Fourth Industrial Revolution. Many of today's school children will be working in jobs that do not yet exist, using technologies that have not yet been invented and solving problems that no one currently envisages. Yet they must navigate this uncertainty and find solutions to these problems. It is the new model of education that will give them the competence to do all this.

V. CONCSLUSIONS

In conclusion, we would like to highlight that there is great potential, but also a great number of risks in the implementation of the intersection of Industry 4.0 and innovation in education and training. Continuous implementation is necessary and must support the changes that have long been called for. In my view, the ongoing technological changes to the content of teaching are sufficient, but the development of critical thinking, creativity and emotional intelligence must not be forgotten. And this is where I see one of the biggest risks of implementing change - we must not forget that Industry 4.0 is not only about robotization and digitalization of production, but also about the consequences that these changes will bring with them and can have a severe impact on people's lives.

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