



The 4th industrial revolution and its implications to the VET provision

Introduction

The goal of this report is to disclose the implications of the 4th industrial revolution for the initial VET provision by paying specific attention to the emergence of the new competence requirements for the VET teachers and trainers.

The main research method applied is desktop research of the articles and studies in the field of the 4th industrial revolution and its implications for the education and, in particular, for the vocational education and training.

The report starts from the brief discussion of the concept of the 4th industrial revolution and its main objects. Then it looks into the implications of the development of the 4th industrial revolution to the structure and contents of occupations and work processes. It leads to the analysis of the implications of the fourth industrial revolution to the qualifications and competences, as well as to the vocational education and training processes - curriculum design, organization and provision of training, assessment of competences. On the basis of this analysis there are analysed the implications of the 4th industrial revolution to the pedagogical and andragogical practices and new competence requirements of the VET teachers and trainers.

1. The concept of the 4th industrial revolution

The Fourth Industrial revolution is considered as a technological development building on the Third Industrial revolution marked by the development of digitalization that has been occurring since the middle of the last century. One of the main characteristics of the 4th Industrial revolution is a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres. The distinguishing of the 4th Industrial Revolution from the 3rd one is explained by the unprecedented velocity of technological changes, its wide scope, and radically deep systems impact.

Navigating the next industrial revolution

Revolution	Year	Information	
	1	1784	Steam, water, mechanical production equipment
	2	1870	Division of labour, electricity, mass production
	3	1969	Electronics, IT, automated production
	4	?	Cyber-physical systems

Compared with previous industrial revolutions, the Fourth is evolving at an exponential pace and disrupting almost every industry in every country by enhancing the transformation of entire systems of production, management, and governance.

The 4th Industrial revolution involved emerging technology breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, quantum computing. One of the essential objects of the 4th industrial revolution is digital fabrication technologies interacting with the biological world by the different combinations of computational design, additive manufacturing, materials engineering, and synthetic biology that leads to the development of symbiosis between microorganisms, bodies, products, infrastructure etc. One of the core driving ideas of the 4th Industrial revolution is to turn the physical object or component, like production equipment into intelligent and active by enabling its interactions with environment by networking. Networking of machines, objects and spaces creates the internet of things which networks the interacting cyber-physical systems with the digital area. For this purpose the objects are provided with the communication modules by enabling them to send, receive, produce and process the data. In this way the whole process of value creation of production starting from the planning and ending with the quality evaluation of the product



or service is networked inside and outside the enterprise what permits to intelligent machines to organize autonomously the processes of production and logistics.

2. The implications of the development of the 4th industrial revolution to the structure and contents of occupations and work processes

Looking to the implications of the development of the 4th Industrial revolution to the structure and contents of occupations and work processes, firstly there can be discerned emergence of the new technological processes, such as:

1. Digitalisation and virtualisation of industrial production by applying and developing of cyber-physical systems (CPS) – networking and connecting of the technical artefacts and processes by using Internet. The spread of CPS in the production, energy supply (Smart Grids) that assists to decentralization of production and energy supply systems (photovoltaic equipment, wind generators, energy accumulation systems) by ensuring smart matching between demand and supply. CPS also provide possibilities to increase the smoothness and safety of the work processes and activities, e.g. in the field of transport by such means as virtual monitoring of the flows of goods in logistics. Digitalisation of production and related management and planning information systems goes together with automatisisation of the usage of data from production lines by the machines. Assessment and delivery of the decision relevant data are important prerequisites for the design of systems of production and logistics. There are used different measures and instruments in this field, such as control software, Big-Data and Advanced Analytics software and intelligent data management systems. These instruments, especially Big Data Networks permit to share and receive the information on the work processes in the quicker ways. It also leads to the development of the standards of data and communication to ensure smooth transfer and usage of the data in the CPS systems. Other effect of this development is melting of virtual and real technological production processes. For example, maintenance and repair of the production systems and units involve solution of the different problems of data interface and communication by using software-driven design of equipment. It

permits the networking of production units in the supply chain and related automatised exchange of data (horizontal integration of the value production chains and vertical integration of production systems). It also enhances integration of the data of units and departments of production according to the functions of the products. From the other side, some functions of skilled employees will survive the introduction of CPS, like production process optimization, solution of problems and removal of control mistakes. However, there is also an opinion, that the above mentioned development of the production process will be gradual.

2. Networking of the all processes of production and logistics aimed to optimize the usage of resources, reduce the costs and increase the effectiveness of production process and its capacity to serve to the needs of customers. This networking concerns sensors and actuators (networking of CPS), networking of the technical systems of production and networking of the overall production chains, starting from the networking of production processes from the autoidentification of information used for networking of process data through barcode systems to the transfer of information on the process organization with RFID and networking of processes with CPS. It permits to exploit the flexible and decentralized control of production process with the intensive application of software for development and experimentation of the concepts and utility of products. Networked production leads to vanishing of automatised pyramid and related work organization – the flows of information in the digital production circulate both vertically and horizontally, increasing cooperation interactions between all levels of employees, as well as intelligent cooperative self-organisation interactions between employees and technological operation systems. Automation models also enable decentralized decision making processes. It favors cluster organization of work based on the collective activity of high skilled employees integrated in the networks and processes. Cooperation between the humans and robots requires other kind of software design and know-how, to keep strict security requirements and to develop security norms and tolerances, as well as development of industry and enterprise specific requirements. These developments also foster effectiveness of the production processes by optimizing cooperation between humans and machines from the process optimization executed by humans, usage of machine

data of process optimization, to the cooperation between humans and machines at the same level, as well as integrated and consistent exchange of data between all involved actors. There also develops the process experience and know-how exchange from the storage of part of process knowledge in the databases controlled with PCs to the exchange of knowledge through enterprise WIKI by transforming implicit knowledge to explicit and universal exchange of knowledge through production chain by using information search functions executed by machines.

3. Individualisation of the production process and increasing it's flexibility through direct involvement of customers and users in the design and production process, what leads to the integration of production and consumption processes (prosuments). Development of the individualized production models leads to the increasing complexity, level of abstraction and requirements of problem solving in the work process, as well as requirements to learn and to develop skills. It increases the demand of the subjective capacities and potential of employees. This process is accompanied with important changes of work organization, especially with increasing transfer and delegation of responsibility to the process level. It fosters development of work process-based work organization by involving teams of employees with the different levels of qualifications, as well as establishment of temporary teams for introduction, implementation and adjustment of the CPS in the production. These developments go in parallel with the process oriented organization of the cooperation of specialists and task groups from the different occupational fields in the implementation of the new technological solutions of the 4th industrial revolution. Work reorganization in the production concerns very wide fields: usage auxiliary measures of production, work tasks and methods, design and development of intelligent workplaces, relationships with suppliers and customers, management and optimisation of the orders, production design and infrastructure, knowledge management in the production process.
4. Facing new challenges and problems of safety and security of society and economy. For example, the fourth industrial revolution increases the role and value of the data in the same time making the protection and security of the data used in the production process of critical importance (protection against data leakages). Protection of the sensitive data is expected to become important part of data management in the

enterprise. Usage of data of the technologies related to the 4th Industrial Revolution will require developing solid data protection procedures. High automatization of the work processes reduces sensibility regarding safety of the production process, what turns into increase of potential risks.

5. More intensive and close integration of the production and transport /logistics systems, what can reduce the demand of intermediating occupations in these fields. There is also expected linking and networking of the different production systems – CAD CAMMES, SAP.
6. Planning, design and implementation of the intelligent work processes. It is also related to the changing understanding of the production process from the isolated and narrow understanding of process executed by the concrete groups of operators to the distribution of the the know-how on the equipment and materials, expanding of the understanding of the partial production processes and their interrelations leading to the holistic understanding of the all work and business processes in the chain of production. Reorganisation of production according to the requirements of the 4th Industrial Revolution means, that such “horizontal” and “transfunctional” work processes, as handling of orders, management of the workflow, development of products and dealing with the infrastructure of the production have to be changed and re-organised in order to ensure smooth transition of materials to final products. It requires the design and use of intelligent workplaces, to apply high quality and effective production methods and to use intelligent assistance functions and technologies. These measures and instruments that support development of high value production processes include digitalization and visualization of production process, workflows, apps, workplace assistance systems, CPS tools, Big Data and simulation technologies.
7. Changing of the quality assurance and management of the production process. These changes aim to attain zero defect production by real time analysis of data and management of self-optimised production and quality processes from measuring and optimization of separate processes to the measuring of the all processes and real time analysis of the data on their failures, ending with the automatised real time analysis, forecasting and prevention of failures in the optimized processes.

8. Emergence of the new fields of activities related to digitalization of work processes and application of the CPS in the production:

- Designing of the new automatised equipment and production lines executed by the engineers with the assistance of skilled operators helping to identify and reflect on needed equipment or simulating of production lines with virtual reality.
- The installation and disassembling of automatised and networked equipment coordinated by engineers and technically executed by the skilled operators. They have to understand precisely the interconnections and transitions of the sets of equipment and the logics of their assembling in the production process. It requires to plan and define networking structures of the value generation chains, sensors and actuators. It also requires to calculate the parameters of process and to propose the data, programmes, schemes, configurations, statistical data, quality control data, networking data.
- Installation and launching of equipment seeking to ensure, that all mechanical, hydraulic, pneumatic, electric and electronic functions are safely executed, ensuring faultless functioning of the all network of production.
- Monitoring of equipment ensuring faultless work of equipment, as well as monitoring and analysis of real time data, observation of the functions of equipment and eventual corrections.
- Process management by continuing observation of processes, identification of faults, their removal and prevention. It requires to overview the control of equipment, using monitoring systems by reading, analysing and interpreting data.
- Data management – reading, analysis and processing the data of machines by recognizing deviations from standard state and faults, optimizing the functions of equipment referring to process and software. It also requires autonomous setting of the parameter data of equipment, correcting of the mistakes in the programmes and analysis of data.
- Maintenance of equipment by executing metalworking, electric and ICT related tasks of maintenance, including execution of preventive maintenance

by producing, preparation and visualisation of the data of servicing and production, operating of the virtually organised maintenance and using of the assistance systems for diagnostics of faults, their documentation and transfer of related information.

- Repair and complex maintenance including IT network analysis; IT supported fault diagnostics, special identification of faults and repair of the complex networked equipment.
- Identification and removal of faults and non-conformities, including diagnostics of the mechanical, electric, electronic, digital control systems, identifying and eliminating the faults and non-conformities of the IT systems and networks.

The advent and development of the 4th Industrial Revolution is also expected to change the structures and processes of the labour market, such as:

1. Loss of simple and routine jobs emerged in the period of the 1st and 2nd industrialization with the increasing rate of substitution of human work with machines. 50 percent of occupations are threatened by automation.
2. Improved quality level and productivity in the high-skilled jobs together with increasing demand of high skilled workforce. This effect can also be reinforced by the expected return of the high skilled production workplaces from the countries of outsourcing. There is expected the growth of high-skilled occupations (e.g. 430 thousands of such new jobs are expected to be created in Germany by 2025). In Germany the enterprises with low advancement in the field of the 4th Industrial Revolution will experience light increase of high skilled workforce and productivity, while those with high advancement in the field of the 4th Industrial Revolution will increase the demand of high skilled workforce by 20-30 percent and will decrease the demand for low-skilled workforce. Stronger interactions between the humans and machines in the production processes will require to design the new forms of these interactions in the way, that would empower the work of humans and would enable effective cooperation with machines.

3. Polarisation of the jobs and occupations caused by the erosion of the intermediary occupations and jobs, that used to ensure and maintain communication between the creative – decision making occupational positions and executors. Digitalisation and digital taylorism pose the biggest threat for such jobs and occupations. These implications are expected to foster segregation of labour market into “low-skill/low-pay” and “high-skill/high-pay” segments, which in turn will lead to an increase in social tensions. The largest beneficiaries of innovation tend to be the providers of intellectual and physical capital — the innovators, shareholders, and investors — which explain the rising gap in wealth between those dependent on capital versus labor.
4. Iterative development of demand of skilled workers and professionals depending on the phases of design, implementation and massive exploitation of innovations in the production. The demand of skilled workers and employees may decrease in the phases of design, implementation and development of innovations, but then again increase in the phase of their implementation and introduction into a mass production.
5. Changing roles and functions of the specialists by increasing weight of the technological and managerial tasks and responsibilities: the preparation of CNC programming and software development can become the functions of technicians, planning and management tasks in plant production, as well as design of production process can become the functions of masters.

3. The implications of the Fourth Industrial Revolution to the qualifications and competences

These changes have important implications to the skills needs. The experience of traditional work processes becomes irrelevant (related to execution and controlling of technical tasks) and the know-how of handling and control of automatised complex work processes becomes important.

Digitalisation of the technological and organizational processes requires digitalization of the human and intellectual capital of the organisations (Digital IQ), especially in the defining, leading and communicating transformations related to digitalization, as well as rolling out

digital processes and services. It would also require significant efforts of change management in the human resource development of organisations, because radical disruptions are usually not comfortable for the people. Enhancing skills and organizational structures in the field of data analytics would be also a crucial requirement for every industrial organization.

Implementation and usage of the complex technologies and their combinations (control technologies, software, production equipment, tooling, IT systems and various interfaces) significantly increases the demand of skills and competencies needed for the managing of complexity, including the understanding of complex control systems and logics of the functioning of equipment, abilities to foresee the impact of introduced change or modification in the production process, abilities to solve the problems of control processes and to control the communication between machines in dealing with mistakes and miscommunications.

Implementation of the Big Data, cloud computing and the Internet of Things in the production process require abilities of software designers to identify interdependencies and to analyse processes.

From the other side, implementation of the ICT technologies in the production process increases the demand of competencies, that are applied in using social media and leads to the change of the contents of the work experience of production operators and technicians, when experience of handling machines of production is pushed out by the new experience of handling of software.

Different technological assistant systems are being designed to help to deal with the shortage of know-how in the usage of automated equipment. It fosters development of the digital taylorism processes, when more and more know-how and practical intelligence is being transferred to the machines.

Dealing with the production technologies of the 4th Industrial revolution would also require new attitudes to the failures and faults of the production processes and machinery. For example, in identifying the reasons of failures and faults it will be needed to look first for these reasons in the data interconnections or their absence and not in the machine itself. More important role will acquire abilities to evaluate intuitively the production data, especially when dealing with complex and multiple combinations of software.

Research on the implications of the 4th industrial revolution for the initial and continuing vocational training in Bavaria (Spöttl et al, 2016) disclosed the increased demand of the following skills and competencies of skilled employees, masters and technicians:

- Handling of hybrid data; ensuring supply of information
- Handling of mechatronical equipment
- Input and processing of the parameter data, manipulate software based control, optimize programmes,
- Handling of the complex equipment
- Handling of the production processes and technologies, ensure continuity and stability of production processes
- Abilities to optimize equipment, competencies in the process optimization and securing, optimize processes and value generation chains by planning software
- Reading, analysing and adjusting of the data of machines
- Reading the live data and correcting of process
- Controlling the faults of sensors and actuators, processing the signals
- Precise identification and diagnosis of the faults
- Design of the software programmes (PC service systems), object oriented software design;
- Repairing of the networked equipment
- Autonomous processing of the maintenance data
- Thinking in the terms of process

The study also disclosed the following key competencies for Industry 4.0:

- Ability to optimize the workflow (planning skills);
- Reading and assessing the data
- Securing the data
- Using data for optimisation of work process
- Usage of knowledge and documentation systems
- Cooperation and communication in teams
- Use system know-how for optimization of processes

- Decision making skills

There were discerned the following ICT related competencies:

- Usage of databases
- Programming of equipment
- Setting the parameters of equipment
- Usage and understanding of the digital controllers
- Servicing of the automatised equipment
- Using of the digitalized networks
- Participating in the software design and programming
- Use the cloud computing.

Specific, work-related competencies:

- To install and launch the equipment
- Servicing of equipment
- Maintenance of equipment
- Servicing of pneumatic, electric, hydraulic and CNC equipment
- Dealing with faults and problems
- Using media for servicing the equipment.

Competencies in the field of electric and metalworking processes:

- Setting of the software of equipment
- Observation of work by using measurement devices
- Reading and evaluation of drawings and diagrams
- Operating complex control equipment
- Identification and removal of faults of equipment.

This study (Spöttl et al, 2016) also disclosed the following field-specific competencies demanded by the transition to Industry 4.0:

- 1.) To analyse, supervise, optimize and develop production systems and networks, including the optimization of the older equipment by connecting different interfaces, MES, SAP, CAD-CAM, data processing units.

- 2.) To apply and adjust IT based systems of assistance and diagnostics, what requires comprehensive approach to applying of network technologies, Firewall, router configurations, as well as abilities to analyse and develop the data processing, to identify and to remove the faults.
- 3.) To analyse, interpret and document production data by using knowledge and documentation systems.
- 4.) To understand and optimize the process structure, contents and networking, by securing the process integration and synchronizing different processes of the production cycle, what requires abilities to calculate the parameters and functions of intelligent devices, to document them in the network and to control them.
- 5.) To execute the maintenance of equipment and to ensure process optimization, by obtaining the required information and applying different media sources.
- 6.) Safeguarding of the functioning of equipment by reading and interpreting the process data of equipment and components, identifying the faults and defects of mechanical components, actuators, sensors, signaling devices, as well as executing routine servicing and maintenance operations and repair.

4. The implications of the Fourth Industrial Revolution to the Vocational Education and Training processes - curriculum design, organization and provision of training, assessment of competences

Changes of the 4th industrial revolution create additional requirements for the organisation and provision of the initial VET.

The literature discerns a wide range of implications of the advent of the 4th industrial revolution related to the changes of labour market and qualifications:

- Polarization of the demand of qualifications due to erosion of middle level vocational qualifications caused by digitalisation and automation of work processes (Kreinsen, Ittermann, 2017; Lee, Pfeiffer, 2017; Spöttl, 2016).
- Hybridisation of high-skilled qualifications and VET curricula on the basis of interdisciplinary know-how and transversal competencies (Spöttl, 2016; Die berufsbildende Schule, 2016).

- Increasing focus of VET curricula and modules to the technological work processes (Spöttl, 2016; Die berufsbildende Schule, 2016).

Existing initial VET systems and models have different predispositions related to the preparedness of the VET provision for the challenges of the 4th industrial revolution. In this regard some authors claim, that the dual vocational education systems are better prepared for the advent of the 4th industrial revolution due to capability of these systems to provide and develop full professional capacity in a broad range of activities creating a good basis for sufficient flexibility in technological and career-related developments (Hartmann, Apt et al, 2017). In this way, training enterprises have the opportunity to provide, in addition to the minimum requirements of the training regulation, additional training or even additional qualifications in order to meet operational or current qualification requirements in the training of skilled specialists. Besides, advent of the 4th industrial revolution requires higher flexibility and individualisation of the VET provision, what can lead to development of the different additional qualifications and modules, as well as to the increasing digitalisation of the vocational learning and training (Hartmann, Apt et al, 2017).

Research study on the implications of the 4th industrial revolution for the initial and continuing vocational training in Bavaria (Spöttl et al, 2016) suggested 4 scenarios of the implications of the Industrie 4.0 for the provision of the vocational education and training.

The 1st scenario claims, that development of the Industrie 4.0 does not cause significant changes in the provision of the VET at least in the short period of time. This scenario supports development of broad basic qualifications with a separation of mechanical, electronic and IT-based tasks. The disadvantage of this scenario is that there is a risk that the current design of the occupations and their profiles in general does not meet the dynamic that takes place real due to the implementation of industry 4.0. This means that it is not feasible to signal that vocational training responds to the developments of industry 4.0, even if these developments only lead to small-scale changes in companies.

The 2nd scenario claims, that the structure of the VET provision will remain unchanged, but the contents (curricula) will have to be adjusted to the requirements posed by the Industry 4.0, such as stronger process orientation, skills in handling of networked equipment, ICT skills and stronger attention to skills for handling CPS. From the first step of a change to the

completion of modified occupational profiles or standards there could pass a very long period of time filled with an intensive negotiating process between the social partners in order to agree on the appropriate focus of a career.

The 3rd scenario expects combination of existing occupations and qualifications. For example, mechatronics can become rather wide occupation strongly related to other occupations, what requires to shift the curriculum design and provision of VET to the work process-based approach. The similar trends can be expected in the occupations of the ICT sector which will become wider and incorporate different aspects of the production technology. This scenario expects integration of occupations and qualifications with the reduction of their number. It will lead to the development of extensive and complex occupational profiles and qualifications, which will present the challenge in organisation of the initial and continuing VET, especially in the small and medium enterprises. It can also lead to the overestimating of the training and reducing possibilities to provide in-depth training for development of particular competencies and skills.

The 4th scenario foresees development of the separate highly specialised qualifications oriented to the requirements and needs of the Industry 4.0. and caused by the need of systemic understanding of the complex intersections and constellations of the different production processes. This scenario implies a very important role for the initial VET and higher education in the supply of these qualifications and presumes reduced possibilities to provide such qualifications in the continuing VET.

Analysing the implications of the 4th industrial revolution to the processes of the vocational education and training there can be outlined different implications to the curriculum design, organisation of the training process, didactics of training and competence assessment.

1. Implications to the VET curriculum design:

- Increasing integration of the different work processes resulting into development of complex and wide competences integrating advanced technological know-how, practical skills and attitudes.

- Increasing inter-disciplinarity and universality (in terms of application in the different work processes) of knowledge and cognitive competences in the VET curricula.
- Increasing flexibility of curriculum design by following dynamically changing skills requirements of work processes.
- Orientation of competences and their development to the process requirements in order to facilitate process approach in understanding and executing of work objectives.
- Focus on the development of attitudes of responsibility and sensitiveness to the environmental and social issues of technological development and innovations.
- Attention to the development of competencies needed for interactive cooperation, knowledge sharing and social solidarity.

2. Implications to the organisation of training process:

- Organisation of the practical training in the networked systems of production and service provision by enabling cooperation between the learners and networked machines.
- Organisation of the training in the complex work and technological processes by applying real and /or simulated technological environments.
- Setting-up and maintaining of the learning networks which involve students, teachers, and trainers, as well as engineers and technicians from enterprises.
- Provision of guidance and counseling to students on the organisation of their learning and work processes by using virtual environments.

3. Implications to the didactics:

- Application of the work process and problem-based learning methods in the context of operating cyber-physical systems.
- Promotion and supporting of independent learning and competence development based on the holistic analysis of the technological and work processes.
- Promotion and supporting of the team learning approaches and methods by involving trainees, experts, knowledge and information systems.

4. Implications to the formative competence assessment:

- Revision and development of the new assessment criteria for the emerging technological and organisational competences.
- Preparation of the new interactive assessment methods adapted for the assessment of the new competences.
- Organisation of assessment of competencies in the virtual space by using cybernetic instruments and measures.

Besides to the implications for the initial VET, the development of the 4th Industrial Revolution is expected to push the development of the continuing vocational training and significantly increase the trend towards spread and development of the learning organisations.

How will these changes and implications change the activities of VET teachers and what new competence needs can there emerge? The answer to this question can be found by analysing new competence needs of VET teachers in the above mentioned processes of VET provision – curriculum design, organisation of the VET provision, didactics and assessment of competences. There can be suggested the following matrix for this analysis:

VET processes	Competence needs of the VET teachers		
		Professional competence (knowledge, skills and attitudes applied in the professional field).	Methodical competence – knowledge and skills applied in the organisation of the work and training process.
Curriculum design and development	Design of the new competences and qualifications related to the execution and mastering of the changed work and technological processes. Know-how and skills on the identification and forecasting of the	Abilities to organise the processes of curriculum design and development processes in the face of emerging competence needs.	Abilities to select and test the pedagogical didactic approaches suitable for the provision of the competences emerging from the development of the Industry 4.0.

	<p>time perspective of the needs of new competences to inform decision making in the curriculum design.</p> <p>Abilities to identify the interlinkages of the newly emerging competences in the curricula.</p> <p>Abilities to update and revise curricula referring to the dynamic change of the work processes.</p>		
Organisation of the provision of training.	<p>Abilities to analyse the work and technological processes and their changes caused by the 4th industrial revolution for the identification of their didactic potential and the most effective ways of the organisation of training in these processes.</p>	<p>Ability to analyse and optimise the work, technological and learning processes.</p> <p>Ability to test and apply the optimal ways of training organisation for the provision of the newly emerging competences.</p>	<p>Abilities to select and adjust the methods and approaches top training to the chosen forms of organisation of training/learning and work in the context of the Industry 4.0 development.</p>
Didactics – application of training methods and approaches	<p>Ability to identify effective training and learning methods and approaches for provision and development of newly emerging competences (effective transmitting of the</p>	<p>Ability to identify and develop methodic approaches for the development of process-oriented attitudes and approaches to work and technologies.</p> <p>Identifying and testing didactic</p>	<p>Skills of demonstration in the real and simulated work processes and workplaces.</p> <p>Abilities to apply pedagogical methods and approaches for explanation of complex interactions</p>

	know-how and skills related to the changes incurred by the Industry 4.0).	approaches and methods that facilitate holistic understanding of work processes based on the interactions between humans and machines and application of cybernetic- physical systems.	between the equipment and humans caused by the Industry 4.0. Abilities to apply digitalised and networked technological measures and instruments of teaching and learning.
Assessment of competencies (formative).	Abilities to identify and test the criteria and tasks of assessment of newly emerging competences referring to their contents.	Abilities to identify and test the formative assessment organisation forms of newly emerging competences.	Abilities to identify and test the formative assessment methods and approaches of newly emerging competences.

This matrix can be used for the further and more detailed exploration and precision of the contents of competences needed by the VET teachers and trainers to provide the competences required by the 4th Industrial Revolution. There can be analysed and explored all suggested dimensions of the competence needs or chosen separate specific profiles of competence needs (e.g., needs of competences for curriculum design or organisation of training provision).

5. Empirical research methodology

In each country there were conducted 3 types of interviews consisting of two parts.

INTERVIEW NO. 1. Implications of the technological changes of the 4th industrial revolution for the work processes and competence needs

Interviewees (informants): production engineers/technicians - at least 1 from the field of mechatronics and 1 from the field of electronics. These interviewees can be interviewed separately (then there will be 2 rounds of interview) or together by answering the questions

one after another (better option). If there is a possibility to get more interviewees it is recommended to enrol them from the enterprises of different size: e.g. 2 from the big enterprise with more than 300 employees (1 engineer /technician from the field of mechatronics and 1 from the field of electronics) and another 1 or 2 from the SME.

Questions of the interview:

- 1.1 How can the **digitalisation and virtualisation of industrial production** by applying and developing cyber-physical systems (CPS), as well as networking and connecting of the technical artefacts and processes by using Internet modify the contents of existing work tasks in mechatronics/electronics?
- 1.2 What new competencies ¹will be needed to deal with these changes of core work tasks²?
- 1.3 What kind of new core work tasks will emerge in mechatronics/electronics due to digitalisation and virtualisation of industrial production?
- 1.4 What current core work tasks can disappear due to digitalisation and virtualisation of industrial production?
- 2.1 How can the **networking of all the processes of production and logistics** change or modify the contents of existing work tasks in mechatronics/electronics?
- 2.2 What new competencies will be needed to deal with these changes of core work tasks?
- 2.3 What kind of new core work tasks will emerge in mechatronics/electronics due to the **networking of all the processes of production and logistics**?
- 2.4 What current core work tasks can disappear due to **networking of all the processes of production and logistics**?
- 2.1 How can the **more intensive and close integration of the production and transport /logistics systems** (linking and networking of the different production systems – CAD CAMMES, SAP) change or modify the contents of existing work tasks in mechatronics/electronics?
- 2.2 What new competencies will be needed to deal with these changes of core work tasks?

¹ Competence is defined as set of knowledge, skills and attitudes needed for the accomplishment of the core tasks and activities.

²Core work task is defined as the task which is essential for the accomplishment of the work process. Usually it includes a number of smaller tasks or functions.

- 2.3 What kind of new core work tasks will emerge in mechatronics/electronics due to the **more intensive and close integration of the production and transport /logistics systems?**
- 2.4 Which current core work tasks can disappear due to the **more intensive and close integration of the production and transport /logistics systems?**
- 4.1 How can the **implementation of the Big Data, cloud computing and the Internet of Things in the production processes** modify the contents of existing work tasks in mechatronics/electronics?
- 4.2 What new competencies will be needed to deal with these changes of core work tasks?
- 4.3 What kind of new core work tasks will emerge in mechatronics/electronics due to **implementation of the Big Data, cloud computing and the Internet of Things?**
- 4.4 What current core work tasks can disappear due to **implementation of the Big Data, cloud computing and the Internet of Things?**
- 5.1 How can **dealing with new challenges and problems of the data protection and security** (like protection against data leakages and protection of the sensitive data) modify the contents of existing work tasks in mechatronics/electronics?
- 5.2 What new competencies will be needed to deal with these changes of core work tasks?
- 5.3 What kind of new core work tasks will emerge in mechatronics/electronics due to **dealing with new challenges and problems of the data protection and security?**
- 5.4 What current core work tasks can disappear due to **dealing with new challenges and problems of the data protection and security?**
- 6.1 How can **application and development of the technological solutions for the sustainable growth and development** (like renewable energy technologies, energy saving technologies, technological solutions for smart distribution of energy (smart grids, etc.), technologies for control of emissions and pollution, etc.) modify the contents of existing work tasks in mechatronics/electronics?
- 6.2 What new competencies will be needed to deal with these changes of core work tasks?
- 6.3 What kind of new core work tasks will emerge in mechatronics/electronics due to **application and development of the technological solutions for the sustainable growth and development?**

- 6.4 What current core work tasks can disappear due to **application and development of the technological solutions for the sustainable growth and development**?
- 7 What are the other possible technological changes of the 4th industrial revolution that can be expected in the fields of mechatronics/electronics? What kind of competencies will be needed to deal with these changes?

INTERVIEW NO. 2. Implications of the organisational changes³ caused by the 4th industrial revolution for the work processes and competence needs

Interviewees (informants): production managers - at least 1 from the field of mechatronics or electronics (there can be involved 2 or more interviewees in the same discussion). If there is a possibility to get more interviewees it is recommended to enrol them from the enterprises of different size: the big enterprise with more than 300 employees and the SME.

Questions of the interview:

- 1.1 How can the **individualisation of the production process and increasing its flexibility through direct involvement of customers and users in the design and production process** modify the contents of existing work tasks (especially in the fields of mechatronics and electronics)?
- 1.2 What new competencies will be needed to deal with these changes of core work tasks?
- 1.3 What kind of new core work tasks will emerge due to the **individualisation of the production process and increasing its flexibility through direct involvement of customers and users in the design and production process**?
- 1.4 What current core work tasks can disappear due to the **individualisation of the production process and increasing its flexibility through direct involvement of customers and users in the design and production process**?
- 1.1 How can the **planning, design and implementation of the intelligent work processes** change or modify the contents of existing work tasks (especially in the fields of mechatronics and electronics)?
- 1.2 What new competencies will be needed to deal with these changes of core work tasks?

³ By organisational changes there are meant the changes that occur in the fields of work and business organisation and management.

- 1.3 What kind of new core work tasks can emerge due to the **planning, design and implementation of the intelligent work processes**?
- 1.4 What current core work tasks can disappear due to the **planning, design and implementation of the intelligent work processes**?
- 1.1 How can **the Industry 4.0 changes of the quality assurance and management of the production process** (like *zero defect production by real time analysis of data and management of self-optimised production; introduction of quality processes based on measuring of the all processes and real time analysis of the data on their failures, automatized real time analysis, forecasting and prevention of failures in the optimized processes*) modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 1.2 What new competencies will be needed to deal with these changes of core work tasks?
- 1.3 What kind of new core work tasks will emerge due to **the Industry 4.0 changes of the quality assurance and management of the production process**?
- 1.4 What current core work tasks can disappear due to **the Industry 4.0 changes of the quality assurance and management of the production process**?
- 4.5 How can **the development of the lean work organization in the production and provision of services** modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 4.6 What new competencies will be needed to deal with these changes of core work tasks?
- 4.7 What kind of new core work tasks will emerge due to **the development of the lean work organization in the production and provision of services**?
- 4.8 What current core work tasks can disappear due to **the development of the lean work organization in the production and provision of services**?
5. What are the other possible changes of work and business organisation related to the advent of the 4th industrial revolution can be expected? What kind of competencies will be needed to deal with these changes?

INTERVIEW NO. 3. Implications of the social changes⁴ related to development of the 4th Industrial Revolution for the work processes and competence needs

Interviewees (informants): representatives of employers' organisations or sectoral social partners in the sectors related to mechatronics and electronics (associations, networks and other organisations working on the national or regional level); at least 1 per country. It is recommended to involve more interviewees in the same discussion: e.g. 1 representing the side of employers organizations (including Chambers of Commerce, Industry and Crafts) and 1 representing trade unions or professional organizations.

Questions of the interview:

- 1.1 How can the **changing approaches to consumption and usage of technologies towards more individualization as well as stronger consideration of the implications of consumption /technology usage to environment** modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 1.2 What new competencies will be needed to deal with these changes of core work tasks?
- 1.3 What kind of new core work tasks can emerge due to **changing approaches to consumption and usage of technologies towards more individualization as well as stronger consideration of the implications of consumption /technology usage to environment**?
- 1.4 What current core work tasks can disappear in the fields of mechatronics and electronics due to **changing approaches to consumption and usage of technologies towards more individualization as well as stronger consideration of the implications of consumption /technology usage to environment**?
- 2.1 How can **the development of communication and cooperation between the humans and CPS** modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 2.2 What new competencies will be needed to deal with these changes of core work tasks?

⁴ By social changes we mean those changes in society and economy that are closely related to the analysed work processes, including customers' behaviour, communication patterns, economic relationships, employment patterns and regimes, education and learning patterns.

- 2.3 What kind of new core work tasks can emerge due to **development of communication and cooperation between the humans and CPS** ?
- 2.4 What current core work tasks can disappear in the fields of mechatronics and electronics due to **development of communication and cooperation between the humans and CPS**?
- 3.1 How can **the development of the sharing economy approaches in the production and provision of services** modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 3.2 What new competencies will be needed to deal with these changes of core work tasks?
- 3.3 What kind of new core work tasks can emerge in the fields of mechatronics and electronics due to **the development of the sharing economy approaches in the production and provision of services**?
- 3.4 What current core work tasks can disappear in the fields of mechatronics and electronics due to **the development of the sharing economy approaches in the production and provision of services**?
- 5.1 How can **the increasing integration of the different occupations and occupational fields (e.g. technological development and healthcare, industry production and service provision)** modify the contents of existing work tasks in the fields of mechatronics and electronics?
- 5.2 What new competencies will be needed to deal with these changes of core work tasks?
- 5.3 What kind of new core work tasks can emerge in the fields of mechatronics and electronics due to **the increasing integration of the different occupations and occupational fields**?
- 5.4 What current core work tasks can disappear in the fields of mechatronics and electronics due to **the increasing integration of the different occupations and occupational fields**?
6. What are the other possible social or economic changes related to the advent of the 4th industrial revolution can be expected? What kind of competencies will be needed to deal with these changes?

The second part of the interviews

Each of these interviews was attended by the VET teachers or trainers involved in the VET curriculum design⁵ and organisation of training processes⁶. In the interview No. 1 on the implications of the technological changes of the 4th industrial revolution for the work processes and competence needs there should participate 1 VET teacher/or trainer responsible for teaching in the field of mechatronics and 1 VET teacher / or trainer responsible for teaching in the field of electronics. In the interviews No. 2 and No.3 it is enough to have at least 1 VET teacher or trainer from one of these fields. It is recommended that the same VET teachers or trainers participate in the all 3 interviews, but if it is complicated to ensure their participation in the all interviews there can be involved different teachers in the each interview.

The role of VET teachers and trainers is to follow the discussion and to make the notes (for themselves) on the issues that are important for the curriculum design and organisation of training. VET teachers and trainers can also participate in the discussions between the researcher and interviewees and to propose their own ideas or suggestions. After the interview with the foreseen interviewees (*production engineers /technicians in the interview No. 1, production managers in the interview No.2, employers organisations or sectoral social partners in the interview No.3*) the invited VET teachers and trainers should remain in the room and answer the following questions:

- 1.1 How the discussed changes of work processes of mechatronics/electronics and related competence needs can change VET curriculum design process? What competencies of VET teachers and trainers are needed to deal with these changes? What could be the best ways to provide and develop these competencies of VET teachers and trainers?
- 1.2 How the discussed changes of work processes of mechatronics/electronics and related competence needs can change organisation of the training process? What competencies of

⁵By curriculum design we mean the process of design and implementation of the initial VET curricula (analysis of activities, preparation and approval of the descriptors of training programmes, testing and introduction of the new training programmes in the educational practice).

⁶By organization of the training process we mean the process consisting of organization of the training sites and places (in the schools and enterprises), funding arrangements, management of the teaching staff (teachers and trainers) and quality assurance of training provision.

VET teachers and trainers are needed to deal with these changes? What could be the best ways to provide and develop these competencies of VET teachers and trainers?

- 1.3 How the discussed changes of work processes of mechatronics/electronics and related competence needs can change application of the didactic approaches and methods in the training/learning processes? What competencies of VET teachers and trainers are needed to deal with these changes? What could be the best ways to provide and develop these competencies of VET teachers and trainers?
- 1.4 How the discussed changes of work processes of mechatronics/electronics and related competence needs can change formative assessment of competencies of students and trainees⁷? What competencies of VET teachers and trainers are needed to deal with these changes? What could be the best ways to provide and develop these competencies of VET teachers and trainers?

Conducting of the interviews – general recommendations

1. Preparation for the interview

Please identify the potential interviewees for the each interview and send the by e-mail the invitation to take part in the interview. This invitation should consist of:

- 1) Introductory letter introducing the project and the goal of interview.
- 2) Questionnaire.
- 3) The competence matrix of mechatronics / electronics or other document in your national language that indicates competencies in the fields of mechatronics and electronics (occupational standards, VET standards, VET curricula, etc.)

All these documents should be translated into native language of interviewees.

It can be indicated that interview will take max. 1,5 hours.

Shortly after sending the invitation the potential interviewees should be contacted by phone to agree the organizational details of the interview (date, time, location).

⁷By competence assessment we mean both the formative assessment that is applied during the training and learning practices and the summative assessment applied for the final evaluation and recognition of the attained learning outcomes.



2. Organization and conducting of the interview.

Most preferable form of interview: face-to-face. In case when face-to-face interview is not possible due to organizational and time management reasons, it can be conducted via Skype or analogue communication platform.

As it is mentioned before, if the interview is being conducted by the person who is not VET teacher or trainer, it will consist of 2 parts, because the VET teachers or trainers have to take part and to express their opinion on the discussed implications of the 4th industrial revolution to the VET curriculum design, organization of training and competence assessment. Participation of VET teachers in this activity can be regarded as their competence development activity and awarded by issuing corresponding certificates (as rewarding and compensation for their efforts and time). The interviewer at the beginning should briefly introduce the project, its main goal and the main outcomes. The interviewees should be informed that the research is anonymous and their names or titles of their organizations will not appear in any document or report related to this research. It is recommended to record the interview with the device of voice recording. Do not forget to ask for consent of interviewees to record the interview.

3. Transcription of the interview data.

Interview data should be transcribed by using the provided questionnaires and putting the summaries of answer after each question. It is recommended to be very concrete and brief in summarizing the answers – please provide the main ideas and suggestions formulated in brief statements. The original quotations from the interviews are not required, unless they can be provided as illustrations to expressed ideas, discussions or suggestions. Languages of transcription: English, German, Italian, Polish. However, if you intend to use your collected information for international dissemination or further research activities (e.g. writing of articles, papers, preparation of presentations for conferences or seminars), you are recommended to translate it in English.

As it is already indicated, the research is anonymous. However, there should be provided the list of interviewed organizations just by indicating the type of organization (e.g. enterprise working in the field of mechanical engineering, trade union, professional organization of

engineers, VET school, chamber of commerce etc.) and (for the enterprises only) – the size in terms of number of employees.

6. THE FINDINGS OF RESEARCH

Profile of competencies required for the working world 4.0 in mechatronics and electronics

The goal of research is to disclose the main technological, organisational and societal implications of the 4th industrial revolution for the work processes of mechatronics and electronics and related competence needs.

Informants in the project partners' countries (Germany, Spain, Finland, Lithuania, the Netherlands, Lithuania and Poland) indicated the following *technological implications* of the 4th industrial revolution for the work processes of mechatronics and electronics:

1. Wider usage of Internet in the work processes of mechatronics and electronics, which requires better understanding of the capacities of the fast Internet (4G and 5G) by the workers, machinery operators, technicians and engineers (4G and 5G).
2. Application of the technological solutions of photonics, optoelectronics technologies, what requires abilities to apply and maintain the equipment and technologies of photonics and optoelectronics in the production processes.
3. Operation and control of automatized and robotized work processes of assembly, in-service, maintenance, also by using mobile devices. Programming and networking of automation and automation drive systems. Here are the quotations from the interviews:

„Basic work task in assembly will be changed even more automatized and robotized. In service and maintenance basic installation task will be remained but are getting more technical by development of equipment. Maintenance and services can do more and more remotework by mobile devices“.

„The activities are increasingly shifting to the area of the programming and networking of automation and automation drive systems. Software for the parameterization and configuration of drives are also increasingly available for mobile devices“.

„Work package will shift from mechanics to electronics and ICT“.

These changes of work processes will require the following competences:

- To use digital measurement- and analysing equipment.
 - To execute PLC - and PC –programming, using interface/control programs.
 - To use new developed sensors, laser technology.
 - To work with networked technologies.
 - SPS programming competence.
 - Abilities to connect the automation and information technology components horizontally and vertically to the Ethernet.
 - Competences in the application of software-based production planning systems /competences for the handling of complex project planning and design of programming systems of different manufacturers in the automation technology.
 - Competencies for the selection and configuration of bus systems of the automation technology (Ethernet, Modbus-TCP, Modbus RTU, CAN, SmartWire-DT, EtherCAT).
 - Ability to exchange of data between different network interfaces and manufacturers (gateways).
4. Dealing with the smaller series and individualised production, executing frequent diverter / adjustment works and operations, dealing with personification and individualization of the products by satisfying individual needs of customers, combination of flexible production design with standardized procedures.

Here are the quotations from the interviews:

„Sizes of series will be smaller, products more tailored to individual customer requirements“.

„Diverter / adjustment works will be needed are much more frequent“.

„Products will get more own intelligence“.

„Intelligence of products should be useable for the ordinary man and woman, so operation must be simple“.

„The requirement of "lot size 1" requires a flexible production design“.

„Due to networking a simple replacement of parts is no longer possible. There is an increased demand for standardized / standardized procedures. The co-worker will experience the lack of autonomy and his/her own creativity will be limited“.

These changes of work processes will require the following competences:

- Abilities to understand and combine different machine programming languages.
- To adjust micro-processors.
- To execute software design and programming by using different programming languages.
- To handle automatic manufacturing systems, also suitable for the production of small series and single pieces.

5. Preparing work manuals and instructions by using different media applications (e.g., Youtube videos).

„Modern manuals and work instructions will be available as You-tube videos.

„Technicians need to able to make/read these books and movies“.

This change of work processes will require the following competences:

- To develop the concept of the accessible work manual/instruction.
- To collect the information and to design the work manual/instruction based on the media applications.
- To update and upgrade the work manual/instruction based on the media applications.

6. Application of trouble-shooting in network-based IT systems for limiting of faults.

„Trouble-shooting in network-based IT systems for limiting of faults is applied“.

This change of work processes will require the competence to apply trouble-shooting in network-based IT systems.

7. Use of autonomous systems with a remote monitoring allowing remote control and monitoring of systems without interference, controlling the equipment, components and individual parts with CPS over remote/virtual environments.

Here are the quotations from the interviews:

„There are initial approaches of installation of autonomous systems with a remote monitoring allowing remote control and monitoring of systems without interference“.

„Clients-disconnection point will shift to an earlier stage in the production process“.

„Alignment and integration of production and logistics processes will increase“.

„The access from CPS over remote / virtual environments will control all equipment, components and individual parts by making them recorded and traceable. The use of unregistered parts in CPS will be prevented“.

„For faster, optimized production of products a design with standardized components will be applied“.

These changes of work processes will require the following competences:

- To install the autonomous systems with a remote monitoring.
 - To apply remote monitoring technologies to control the equipment, components and individual parts with CPS.
 - To execute the maintenance of the autonomous systems with a remote monitoring.
8. Application of industry-specific software products for production planning and preventive maintenance (PPS, ERP, MES, CAQ). Working with industry-specific software products and the use of production planning systems (PPS, ERP, MES) in the small and medium - sized enterprises which will be suppliers and sub-suppliers.

„Increasing the number of processes, orders, and fulfillment“.

„Reducing inventory“.

„There will be a need to implement a program/an application that could handle an entire branch of supplier and customers“.

These changes of work processes will require the competence to use the industry-specific software products of production planning and preventive maintenance (PPS, ERP, MES, CAQ) to handle the order execution at the production unit.

9. Applying remote maintenance solutions for the production machines. Executing maintenance by applying visualization software and assistance systems.

Here are the quotations from the interviews:

„The employees have to be present increasingly rare at maintenance work as the remote maintenance for instance by using a safe VPN tunnel to get access to production machines becomes easier and more comfortable. That leads to cost saving and ease the burden on the environment“.

„The implementation of visualization software and assistance systems to a simplified system maintenance“.

„In order to minimize downtime and thus costs, information on the wear and tear of plant parts from a continuous monitoring of the machines by sensors, is evaluated. The procurement of spare parts is then "Just in time "with the support of software such as SAP“.

„In connection with the further development of technical production process there can be foreseen use of increasingly intelligent and autonomous machines. This results in the necessity for communication between man and machine“.

„The life cycle of components of machines and plants will be individualised through a continuous process of data acquisition and will no longer be subject to fixed maintenance cycles (Keyword: "health index" of a machine)“.

„Work tools are becoming more "smart" and offer through integrated access to assembly information the possibilities to avoid faults. (E.g., an "smart" torque wrench automatically detects the allowable torque for one screw connection)“.

These changes of work processes will require the following competences:

- To perform individualised maintenance of components of machines and plants by using continuous process of data acquisition.
- To implement visualization software.
- To evaluate the information on the wear and tear of plant parts from a continuous monitoring of the machines by sensors.
- To execute “just in time” procurement of spare parts with the support of software.
- To execute compilation of production systems.

10. Handling the networked production units belonging to the chain of value creation connected to the Internet:

- Processing on-line inquiries and placing of the offer
- Handling of the automatically placed orders.
- Calculations of production costs.
- Setting up technological processes via Internet applications.
- Organisation of production: dealing with on-line work schedules and norms, benchmarking of the production processes in the workplaces, optimisation of the work organisation and execution by applying LEAN.
- Quality assurance: on-line setting of the norms and procedures, assessment of quality and reporting to customers.
- Logistics and delivery: packaging and labelling.

Dealing with absolutely integrated processes of production and logistics (internal and external). Dealing with the integrated chains of value creation that establish strong interdependence between the customer and producer.

Here are the quotations from the interviews:

„By the linkage of production processes the whole expiry of a work order including the offer, the complete transaction (planning, production, commissioning) and the maintenance and the repair gets more transparent“.

„The use of computer-aided software solutions in the production and logistics of the SMEs/. SAP is, for example, such a computer-assisted ERP system (Enterprise Resource Planning) which can help to adapt individually all production and logistics processes of a company.“

“Reduction of the need of improvised repair and maintenance work“.

„Autonomy devices and adaptive systems. Intelligent process control“.

„Intelligence enhancing products and systems“.

„Further minimizing with far-reaching intelligence of the products“.

These changes of work processes will require the following competences:

- To work with the visualization and assistance systems.
 - To apply networked planning and product management systems by using mobile terminals.
 - To be able to modify and test drive the different possible settings and parameters in a process.
 - To use digital planning tools and mobile terminals for the planning of work.
 - Creating new algorithms and applications in order to link many things and common synchronization with the entire value stream.
 - Data analysis.
 - Knowledge of economics.
 - Time and production management.
 - To adjust working time organisation to requirements posed by communication with customers, suppliers and partners located in the different time zones.
 - To perform independent work and individual business organisation by applying on-line solutions.
 - To ensure and maintain the access of customers to monitoring and controlling of the own production process, including the production schedule and costs.
 - To ensure mutual transparent monitoring of the production management systems.
 - To execute intelligent process control by using autonomy devices and adaptive systems.
11. Executing continuing monitoring and adjustment of networked automatic manufacturing systems (can be of the different production processes).

Here are the quotations from the interviews:

„Increasing the processing efficiency and accuracy of the product, reducing employment, and remote working“.

„Tasks will be carried out using one application. One administrator will be able to handle the tasks of many factories merged into a single body“.

„Continuously condition monitoring, more precise adjustment of production plants, faster conversion to different products“.

This change of work processes will require the following competences:

- To execute the monitoring of networked automatic manufacturing systems.
- To adjust networked automatic manufacturing systems.

12. Transformation of the projects based on the software into industrial projects.

Quotation from the interview:

„Work will be changed more flexible and location independent. Work will become more realtime and even more sectional. Nature of the work will be more "just on time" style: imagine the last gateway IoT2020 by Siemens, we used this hardware to transform all projects based on Arduino software into industrial projects, PLC working processes compatible. This is open innovation, which is making everything more efficient, faster and flexible“.

This change of work process will require the competence to transform the projects based on software to the industrial projects by using PLC working processes.

13. Operating and using automated supply chains which network and integrate the logistical processes inside and outside production plants up to a decentralized real-time control of the logistic networks.

Quotation from the interview:

„Increasing automation of the supply chains, including the networking and integration of the logistical processes inside and outside production plants up to a decentralized real-time control of the logistic networks“.

This change will require the following competencies:

- To master the implementation of information infrastructure of automated supply chains.
- To use the process interfaces of the assistance systems as well as devices with local intelligence and decision capability.
- To use material procurement management systems and the online portals of wholesalers for material procurement.
- To use the QR codes of production systems.

14. Working together on cloud, personalizing each products and production phase, using sensors.

„This process will offer new employment possibilities for non-tech professionals, or just techlover they will be now more interesting for companies“.

This change will require the following competences:

- To apply identification systems (e.g., RFID) as well as system and communication interfaces (OPC UA, ODBC).
- To create productive and logistics cooperating models.

15. Application of 3D printing technologies.

Quotation from the interview:

„Using 3D printers and other tools to create what you need“.

16. Using the services provided by the data-centers in the field of sorting and delivery of data. Decision making in the production and maintenance processes and operations by using and assessing Big Data, development of Big Data solutions.

Here are quotations from the interviews:

„Data is centrally collected and processed leading to increasing complexity of data structures more“.

„Decisions in the course of e.g. a maintenance process which formerly the skilled worker has executed, will be in large parts taken over by "Big Data. The skilled worker is increasingly only executive power“.

„The use of technicians work becomes more efficient and flexible by accessing information that is in cloud-based systems (assistance systems)“.

„Cloud computing will be the solution, the only way looking for resources online. Once you are connected you don't need a powerful device, you only need a good connection. You won't be working only on your data that you have collected, but on all the data available online collected by everybody. All sensors you will be using will put all the information collected online“.

These changes will require the following competences:

- To analyse and select relevant data for the execution of work.

- To propose the solutions for application of Big Data in the production process by referring to the existing knowledge of the physical, technological and business (commercial) interrelations.
- To use the data from the cloud or BigData for the formulation of inquiries as well as to evaluate the data.
- To benchmark and compare production data on the level of workplace and on the level of enterprise / sector (between the different operators and producers).
- To execute maintenance of the production control systems based on Big Data and clouds.
- To evaluate and prove the validity of production/maintenance information from Big Data and clouds.

17. Executing the data security and data protection procedures in the networked automation and drive system: the establishment of access protection for automation systems as well as setup of IT networks using network routers, use of encryption and secure encryption passwords, an assessment of the sources in searches, the usage of security cameras, etc.

Here are some quotations from the interviews:

„Sensibilisation of employees on the issues related to data protection for the safe production process“.

„Increasing safety regulations of the use of IT (including mobiles phones) in the production process“.

„Developing security rules, the sensitizations of every single employee and the control of the compliance of the operational security rules is necessary“.

These changes of work processes will require the following competences:

- To deal with safety-relevant process steps and the corresponding steps in the software application.
- To take safety risks through consistent use of existing safety measures (Backup, use of VPN and encryption, authentication, Anti-virus software, etc.).

- To establish the access protection for automation systems as well as setup of IT networks using network routers.
- To protect customers data in the case of production of personalized products in order to ensure, that personalized products would not get into mass production.
- To protect the data in the personalized after-sales service and related contracting.
- To handle new models and technological solutions of protection against hacking.
- To apply business and production data and know-how standardization procedures to ensure data security, especially in the field of business-to-business.

18. Handling and maintenance of the sensors and sensorics systems. Controlling of machine data and machines themselves with the help of sensors; tuning of machines in the production processes and systems by using sensors. Working with the multifunctional sensors used in the production processes.

Quotations from the interviews:

„Think about sensors tracking parameters of your environment, the sensors sending information to the cloud, the cloud giving feedbacks to your machines/robots working in your environment. This process will also be focused on making your production chain more sustainable“.

„IT enables the complete recording of energy data of all subsystems. It allows for a far-reaching energy management“.

„Analysis of the working environment, definition of sensors to place, elaboration of strategies thanks to the information collected“.

These changes will require the following competences:

- To analyse the working environment with use of sensors.
- To control the machines with the help of sensors.
- To tune the machines in the production processes and systems with the help of sensors.
- To define the sensors to place.
- To use multifunctional sensors.

- To develop smart algorithms.
- To elaborate the strategies on the basis of collected information.

19. Complying the energy saving procedures and regimes in the work processes, usage of energy management systems in the mechatronics and electronics.

Here are some quotations from the interviews:

„By legal requirements (ERP-Guidelines) is the use energy-efficient equipment. For companies energy saving measures are becoming increasingly important. For this purpose, for example, there can be used energy management systems“.

„With an energy management system, the primary energy consumption can be reduced and thus a preventive environmental protection (Clean production) enabled. In addition to the increased environmental performance the climate protection is also enhanced by the increased energy efficiency in the same time reducing sustainably the operating costs“.

„Through the use and development of new technologies new fields of activity are also emerging in the electrical trade“.

These changes of work process will require the following competences:

- To execute installation and start - up of battery packs for PV systems.
- To execute maintenance of battery packs for PV systems.
- To install and program smart home and smart grid systems and components.
- To use and exploit sustainable energy and environment friendly technologies in the production processes.
- To apply the mechatronic technologies, analogue controllers and sensors in the control of the hydro and wind energy generators.
- To combine multiple energetic fields into the onesolution.

There will dissappear the following routine work processes based on manual operations:

- Manual mechanical work steps in metal processing as well as more and more in electrical wiring, particularly in case of small series and single products.

- Core work tasks as manual processing of e.g. a control cabinet to prepare the placement and wiring with electrical components.
- Setting up the machines (a machine will be set up by itself after entering unchanged data).
- Products packaging.
- Storage.
- Products stickering.
- Stationary quality assessment.
- Tasks connected to traditional ideas of transportation system.
- Commercial profile or an agent.
- Core work tasks in the field of classical electrical engineering, (e.g. the area electrical installation, the foundations of the metal processing and basic protection measures VDE 0100, these areas are currently still a subject of the electronic equipment for operation technology).
- Pneumatics will become less and less important due to development of the electric drive technology (servos) and environmental standards (IE3) requiring more energy efficient use of actuators.
- Core work tasks in the field of fault - finding.
- Replacement of components or troubleshooting.

Informants in the project partners' countries indicated the following *organisational implications* of the 4th industrial revolution for the work processes of mechatronics and electronics:

1. Development of more individualized models of work organization, such as in-sourcing, when the equipment belongs to the different freelancers sharing responsibility for the quality of produced products and services. Shift of the part of blue collar work in mechatronics and electronics from the workers/operators to the free-lancers or individual subcontractors providing production services. "Factory in factory" model, when the separate units of production are flexibly integrated in the sectoral, inter-sectoral, or international chain of value creation.

Here are some quotations from the interviews:

„Work will be become more project style and it's contents will be split into smaller tasks and these will be more unique than earlier“.

„Work will be changed to Project-style and contents of work will be divided into smaller pieces and they are more remarkable individual than before“.

„Order comes with the information on delivery and assurance of logistics in the production process“.

„Integration of the internal and external logistics of production“.

„The new management centers will be virtual hubs organizing tasks'flow for all other spots, you will need to work there in the information's management“.

„Sharing technologies“.

„The traditional idea of industrial district will probably change, your production house will be there only if specifically needed or in case you are closer to a relevant source. Otherwise you will be sharing all technologies online and using terminal littleproduction machine wherever you are to produce what you need and how you like it. The idea of transportations will be different“.

These changes of work process will require the following competences:

- To work with new kind of user interfaces.
 - To apply the free-lancing business model in providing production services.
2. Increasing complexity of the planning of production and handling of production equipment (set-up, usage, maintenance) due to increased production flexibility and personalization. Flexible and individualized organization of production, as well as internal and external logistics. Optimizing internal logistic and production flow management.

Here are some quotations from the interviews:

„The volume of production batches will be reduced what will require to increase the flexibility of production and the operation and maintenance of the related equipment will become increasingly sophisticated“.

„Planning and execution of production processes by using very flexible production and assembling facilities and equipment. The work processes will contain more tasks that are related to planning and design of work“.

„Instead of considering the point of departure the product itself, you will start from a matrix or a module to be personalized. This is mainly an advantage, because you can offer a better service to your client and you are always in a development process.“

„Producing customer-oriented, just-in-time production, no / less stocks. Because smaller batches, much more attention for changeovers and commissioning of production facilities. In big companies (like Barilla, Coca-Cola, etc.) optimizing internal logistic and production flow management is very important“.

These changes of work process will require the following competences:

- To plan and execute production processes by applying very flexible production and assembling facilities and equipment.
 - To apply the flexible approaches of the work organisation and the operation and maintenance of the related equipment in the workplace.
3. Virtualisation of some work processes, such as design and testing.

Quotation from the interview:

„ By collecting large amounts of data, we can create a computer simulated copy of the real process. In that environment, we can test various optimizations and individual-rationalization of the process. The data will enable suppliers and customers to gather together“.

This change of work process will require the following competences:

- To apply computer simulated copies of the real work process in solving the production problems.

➤ To test optimizations *and individual-rationalization of the production process.*

4. Taking control of the whole value creation chain in one workplace.

Quotation from the interview:

„Hopefully we can take control of the entire chain - purchasing, logistics, manufacturing, sales and recycling“.

This change of work process will require the competence to install and integrate various electrical and mechanical components into one solution.

5. The multiplication of consumption and production processes.

Quotations from the interviews:

„Imagine you can create and personalize everything at home/from home for a cheaper price“.

„ You will be pushed to buy/build/construct/use more and more things, the things you need. The idea will move from the global “the same product, anywhere you want” to the new “the specific product you need, where you are”.

6. Rapid and iterative organization of the design and construction processes.

Quotation from the interview:

„The analysis of the customers’ needs, rapid “prototyping” solutions, iterative construction of the target solution“.

This change of work process will require the following competences:

- To analyse the customers needs.
- To apply rapid “prototyping” solutions.
- To apply iterative construction of the target solution.

7. Fragmentation and alternation of work organization between the real and virtual work processes and environments.

Here are some quotations from the interviews:

„Current time and location binded core work tasks will be changed because of smart industrial systems. Real time monitoring will change the framework of the processes' implementation“.

„We will be able to work more with computer simulation models and forecasts based on collected data. We will build the entire process virtual in order to improve and optimize“.

„Work tasks which are in "digital world" will require understanding of networking and project managing, operation of digital world“.

This change will require the following competences:

- To apply the new kind of user interfaces.
- To work with secure computer communication, combined with the hardware.
- To review and analyse all the production and assembling processes and to provide the feedback for quality control of these processes.

8. Cobotics– cooperation between humans and robots in the workplaces.

„New machines and robots will change the approach to what is normally considered the needed working time. We will need less human working time. At first it will be more connected to heavy works“.

„The necessity to cooperate with machines and intelligent systems“.

This change will require the ability to apply the work safety requirements for work with cobots.

9. Integrated quality assurance processes.

Quotations from the interviews:

„The need to use complex systems to analyze and evaluate the quality of work will increase“.

„Quality assurance will be integrated in the designing and production processes. Already at the stage of designing the quality assurance will be planned and defined“.

„Integration of the feedback of quality control in the production and assembling processes“.

„Monitoring, real time interaction, data analysis.“

This change will require the following competences:

- To use complex systems to analyze and evaluate the quality of work.
- To handle the feedback of quality control in the production and assembling processes with integrated quality assurance.
- To deal with the monitoring and real time interaction in the integrated quality assurance processes.

10. Individualisation and increasing social orientation in the field of quality assurance.

Use of the expert and intelligent data processing systems for quality assurance.

Here are some quotations from the interviews:

„Thinking about UBER or other similar new business more and more people will be implementing new individual job, creating their job opportunities. In this case also the idea of a quality service will be different and recognized differently, more socially defined“.

„The changes will lead to the reduction of the tasks and activities of the quality control of made elements“.

„Expertise tasks which require special skills and knowledge“.

This change of work process will require the following competences:

- To execute interaction with help desk and technical support, on line assistance.
- To analyse and identify quality errors sources in the intelligent processing systems.

11. Increasing importance of data analysis for the running and development of the technological and work processes of production.

Few quotations from the interviews:

„Analysis of data together with technology are getting bigger role“.

„Collecting data about functioning and all operations, monitoring for the moment when it will be needed“.

This change of work process will require the following competences:

- To utilize of real time data.
- To work with intelligent systems.

12. Intensifying and changing cooperation between the producers and customers in every step of production process starting from the product design.

Here are some quotations from the interviews:

„Intensive cooperation and consultation will be more crucial than it is now. Consultation, driven bottom up is required. Reconciliation between the clients designers and producers, finding consensus together“.

„Structural consultation in the workplace with employers“.

„Main contractor will play a lower primary role. Subcontractors will get more responsibilities. Strictly deal with quality control, safety and the environment, security of data and processes.“

„Reducing failure costs needs more attention, also interoperability. In order to pursue a more predictable quality. This can be achieved with fixed structured processes“.

„Acceptance procedures and to comply with agreed procedures“.

„Malfunction and failures will have a greater impact on the production process and will therefore have to be minimized. Avoiding production failures because the impact is going to be bigger“.

„3D visualization and modelling: e.g. automated clash detection to discover design conflicts“.

This change will require the following competences:

- To execute and maintain constant consultations with the customers, designers, main contractor and subcontractors.
- To deal with quality control, safety and the environment, security of data and processes.
- To reduce failure costs by applying fixed structured processes.

- To comply with agreed acceptance procedures.
- To minimize and prevent malfunction and failures.
- To apply 3D visualization and modelling to detect design conflicts.

13. Increasing standardization of the maintenance process.

Some quotations from the interviews:

„Aiming for more standardization, rapid availability of components, only specials in stock“.

„Building Information Management (BIM)“.

14. Further application of LEAN production models.

Some quotations from the interviews:

„Reduce the amount of work tasks by better planning“.

„Increase the effectiveness of working, prevent employees idling“.

„Where the cost of people working hours is higher, the transformation will be faster. In other environments/countries hiring people is cheaper than investing in innovation“.

„The team of producer will also include suppliers to further improve production“.

„It will be possible to produce more models in the same factory, in the same lines. And test prototypes faster, reducing costs“.

„Efficiency of working is getting higher, less jobs in same work in the future, meaning of expertise is getting more important“.

„A work organization with a mix of work and leisure instead of fixed working hours“.

This change of work process will require the following competences:

- To adapt to changing operations by constantly updating the basic data systems.
- To cooperate with the intelligent systems.

- To maintain the news production data (technological and constructional) in used intelligent manufacturing systems.

15. Active examining the efficiency and sustainability of the production processes by the employees.

Some quotations from the interviews:

„Examining the efficiency and sustainability of the production processes, recommend improvements / adjustments“.

„Optimizing the efficiency of the production process. Reduction of stock material is crucial“.

This change of work process will require the following competences:

- To examine the efficiency and sustainability of the production processes.
- To recommend the improvements and adjustments of the production processes.
- To optimize the efficiency of the production process.
- To reduce the stock material.

16. Emergence of interactive work processes.

Quotation from the interview:

„It will create the new work tasks in the field of servicing and repair. For example, there will emerge the task of development of interactive repair and assembly instructions that use the possibilities of virtual reality (development of the virtual solution of repair and assembling“.

This change will require the ability to develop interactive instruments and measures that use the possibilities of virtual reality.

17. Multi-tasking and multifunctional contents of work tasks and processes in electronics and mechatronics. Spread of multitasking in teams.

Some quotations from the interviews:

„ The work package for mechatronics / electronics technicians will only become more extensive. Up to a certain level, a technician can handle/ oversee this. If the depth /

specialization increases, dividing into mechanical technician and electrical/automation technician an ICT technician will be necessary“.

„ The cooperation of the different production units and departments in the field of design, production and service must be improved. A new work model will be drafted and implemented in teams. A new routine develops so that all the employees can work in every field. Departments will be merged within these team structures.As a team you are more flexible in your tasks and working fields“.

These changes of work process will require the following competences:

- To deal with the multiple tasks in the fields of mechatronics and electronics.
- To oversee and to plan the multitasked operations in the fields of mechatronics and electronics.
- To cooperate with the different production units and departments in the field of design, production and service in dealing with multiple tasks.

18. Diversified responsibility due to emergence of the new tasks, offers and transitions between the different fields of activities. Increasing expert status and responsibility of the production workers facilitated by the intelligent machines and expert systems.

Some quotations from the interviews:

„The areas of responsibility are more diversified. Hereby the employee‘ motivation will be increased as new tasks which before have not been part of the field of work have to be done. A flexible fall back on other work fields is possible“.

„The diversity of the offers is rapidly changing. Therefore the companies have to be accordingly equipped“.

„Changes regarding the professions, adaption to the diversity of offers“.

„A person ceases to be a worker, and becomes an expert in use of intelligent machines, and therefore must have the ability of handling, programming, maintenance and supervision of integrated automatic systems operating in a highly computerized environment.“

This change of work process will require the following competences:

- To handle integrated automatic systems operating in a highly computerized environment.
- To programme integrated automatic systems operating in a highly computerized environment.
- To maintain integrated automatic systems operating in a highly computerized environment.
- To supervise integrated automatic systems operating in a highly computerized environment.

There will disappear the following work tasks and processes:

- Current time and location bind core work tasks removed by smart industrial systems.
- All operations connected to repetition of tasks, movements, sequences, etc.
- Isolated tasks.
- Introducing minor corrections to the construction and technology of the produced product.
- Manual adjustments of machines and processes.
- Quality assessment of made elements by operator.
- Traditional maintenance operations.
- Manual control measurement.
- Reporting about the performed operation.

Informants in the project partners' countries indicated the following *societal implications* of the 4th industrial revolution for the work processes of mechatronics and electronics:

1. Emergence of business models based on the direct relationships with final customers and users requiring higher flexibility.

Quotations from the interviews:

„New digital technology and its availability for a reasonable cost is changing the whole environment. In this moment many companies who started using 3D printers

are changing their business model, giving more relevance to the direct connection with the final customer“.

„Processes and employees indeed must be more flexible in the future and very willing and preparedness to fill customer needs“.

This change of work process will require the following competences:

- To organise flexibly working times for workplace.
 - To handle the tasks of electricians for automation, including maintenance and assembling.
 - To ensure the smooth transferability of the systems of machines on further systems with the same systematic.
 - To act in highly robotized environment.
2. Changing pathways of employment and employee mobility with increasing mobility and stronger role of production workplaces.

Quotation from the interview:

„Many fields are covered, strong mobility is available. At first the trainees go in the production area and finally in the departments“.

This change of work process will require the following competences:

- To analyse the work processes and their requirements.
 - To design the individual career pathways in the production area.
3. Optimisation of the work processes in terms of consumption of time, materials, energy resources.

Quotation from the interview:

„Optimisation of work processes will take place. We will go towards production to order instead of the stock. We will try to recycle instead of throwing. Small-scale energy production, etc. This will mean a higher degree of automation and the need for quick and easy conversion of production“.

This change of work processes will require the following competences:

- To analyse critically the technological solutions and applied work organization approaches.
 - To suggest the ideas on the optimization of the work processes of mechatronics and electronics.
4. Emergence of the new combined and complex occupations in the field of mechatronics and electronics.

A quotation from the interview:

„Demand for occupations such as: mechanic in automation (worker, technician), software engineer, production engineer, automation system designer or mechatronics technician; as a result new professions may emerge from a combination of existing professions increased demand for customized products, produced on an individual order, customized to customers' preferences and needs“.

This change of work processes will have the following implications for competences:

- Merger of different core competences.
 - Increasing role of inter-field competences.
5. Creation and management of physical products with a digital soul.

Quotation from the interview:

„Visionare who is able to see, e.g. statistical probability, what customers consumption habits will be and who follow changes on companys's sector“.

6. Development of adaptive manufacturing processes.

Some quotations from the interviews:

„ Adaptive manufacturing will be developed. We will coat a recycled material with a new wear surface. Here comes the new methods and tasks to be developed“.

„ New tasks will be related to:

- *working in a highly automated and computer environment*
- *abilities related to producing meindividual products*

- *the use of the new innovative solutions from various areas (workorganization, technology, services)*
- *generating growth opportunities of the degree of production automation*
- *supervision of data exchange in real time within the company and between the other elements of network, e.g. the client*
- *taking permanent actions to increase flexibility, and increasing the efficiency of production*
- *communication and counseling skills in relation customer - producer“.*

This change of work processes will require the following competences:

- To work in a highly automated and computer environment.
 - To produce and develop individual products (craftsmanship).
 - To apply production automation technologies.
 - To exchange the data in real time within the company and between the other elements of network, e.g. the client.
 - To apply flexible work organisation methods and approaches.
 - To counsel the colleagues and customers.
7. Controlling of the increasing complexity in production through intelligent assistance systems. Control of the production process through augmented and virtual reality. Simplification of the handling of the new automation and control systems through digitalization leading to replacement of human work by machines. Strengthening of the supportive functions of technologies to the human abilities and work performance.

Some quotations from the interviews:

„These systems will help to filter and process the large amounts of data. Intelligent assistance systems will play a crucial role. Humans are more likely to operate at the level of surveillance systems and will have to interpret recorded data and to make decisions“.

„Prototyping, smart productions, 3D printers, robots, sensors have changed and will change the production process“.

„Digital is more and more for everybody, and it’s entering the world of physical objects. Bits are ruling over atoms. Work tasks will be changed from manual labour to process monitoring tasks“.

„Digitalization processes are present in many manufacturing companies or is on the way to this goal. The handling of the new automating systems are not more difficult than earlier, rather easier, but the processes behind have become more complex. Human resources are saved and replaced by automatic processes“.

„Voice control and voice recognition will play a big role in the future“.

„We will get more intelligent systems that work both safe and intuitive to so improve both the production and safety. In automated cyber-physical systems (CPS), a person will be in a center of the intelligent center where a technology will support the human’s cognitive and physical abilities“.

„CPS interaction“.

„Expert tasks, multi-industry professionals“.

„Training regarding changing processes. Improving the principles of cooperation and support between workers and CPS“.

These changes will create the following requirements for competences:

- To handle robots and automation systems integrated in the production processes.
 - To manage intelligent systems.
 - To take professional and flexible actions in an environment of highly automated production processes.
 - To keep the systems running.
8. Open and cooperative elaboration of products. Sharing management systems.

Quotations from the interviews:

„Open-source, crowdsourcing, big data, analytics, etc. are changing the way to elaborate a product. The 1st FabLab in Boston started in 2001, from that point the

idea of a place where you can build/construct/make almost everything moved to the idea that anybody can build anything cooperating connected with other people. Think about the Italian creation of Arduino, a hardware project open-source easy to handle. In e-mobility development of autonomous systems will be speeded up by development of the sharing economy. Popularity of electric vehicles sharing services is currently increasing. Autonomous electronic systems for sharing management are required to be developed more safe and dynamic and easier to use“.

„Social acceptance of an economy of sharing, if advantages for users e.g. an attractive electrical car in car-sharing instead of an own car“.

These changes of work processes will create the following requirements for competences:

- To program the production processes.
- To apply and adjust autonomous electronic systems for sharing management of production processes.
- 9. Increasing complexity of work tasks and responsibility of the work performers in the field of work optimization. Re-shaping all technical-based profiles towards higher interdisciplinarity, multitasking and spread of teamworking.

„The digitalization includes many possibilities but also risks. The attractiveness of the user does not play an important role“.

„The work tasks will:

- *be more and more complex*
- *require the perfect knowledge of the equipment, its possibilities, and the ways of equipment and programs retooling*
- *generate the permanent need for finding the ways of improvement of the productivity and reduction of the manufacturing costs, as well as improvement of cooperation and support principles between workers and CPS“.*

„The know-how of current professionals will be diversified and differences between various professions are not that clear in the future“.

„Extremely increasing number of new trainees because of a high demand of motor mechanic and electricians“.

„During the shell teams develop and implement work models. Hereby a new routine develops, so that every employee can be active in every department. It can lead to the integration of the different functional departments of enterprises. As a team the employee is flexible in it's tasks and areas of responsibilities“.

„The efficiency is supported, in a long-term more employment is available and less waiting for orders is necessary. The areas of responsibilities are much more diversified“.

„Abandonment of the knowledge of individual tasks performance for the benefit of broad and interdisciplinary knowledge“.

These changes of work processes will create the following requirements for competences:

- To cooperate with robots.
- The ability to use the newest and innovative solutions in the interest of activities.
- To generate the permanent need for finding the ways of improvement of the productivity and reduction of the manufacturing costs, aswell as improvement of cooperation and support principles between workers and CPS.
- To develop and implement work models in teams.

10. De-skilling of tasks and reduced importance of technological expertise. New employment opportunities for low qualified workforce due to usage of intelligent assistance systems.

Some quotations from the interviews:

„Tech projects for non-tech experts“.

„The need of automation system operators“.

„The new employment opportunities will be accessible to adolescents with low qualifications by usage of the intelligent assistance systems that will not require new level of training“.

These changes of work processes will require the ability to manage and apply assistance systems and tools.

11. Spread of mechatronics in many areas. Increasing interweaving of professional fields what will require more interdisciplinarity.

Some quotations from the interviews:

„We are now seeing a trend in the service sector. This means of course that we will see the development of services and products that we might want to use in the industrial sector“.

„There will be an increasing interweaving of professional fields what will require more interdisciplinarity. The professional positions can will become more similar to each other or integrated (Machining technician, product technologist). Therefore core competencies will be of more value than pure expertise and will provide more flexibility“.

These changes of work processes will require the ability to cope in a highly automated environment.

12. Flexibilisation of work time and space.

A quotation from the interview:

„There can be expected the change of the definition of working time and space with the spread of teleworking“.

This change of work processes will require ability to adjust to the new ways and models of management of working time and space (24 hours designing, sharing workplaces, etc.).

13. Adaptation to changing consumption habits and consideration of the requirements of responsible consumption in the production process.

A quotation from the interview:

„People consumption habits will change which force industrial production and industrial workers adapt even more flexible and all the time changing production process. Industrial workers must participate planning of production and production management also“.

This change of work processes will require the following competences:

- To participate in the planning of production.
- To participate in the production management processes.

There will disappear the following work tasks and processes:

- *Risk to craftsmanship and requirements to reshape its value in comparison to digital manufacturing.*
- *Reduced needs of actions related to evaluation of the quality of production processes.*
- *Ordering parts, raw materials, components; making additional arrangements with other chain links.*
- *The importance of experience is diminishing, "the augmented reality presents how I need to turn a screw".*

Necessary future competencies of VET teachers and trainers with requirements for future-oriented teaching in mechatronics and electronics

The interviews with the VET teachers and trainers helped to disclose the following requirements to their competences (see in the table below):

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
Competencies needed to deal with changes in VET curriculum design		
<p>Ability to integrate the technological and organizational changes of the work processes of mechatronics and electronics in the VET curricula.</p> <p>IT competence for teachers in automation and electrical engineering.</p> <p>Skills and competences of electrician-informaticist.</p> <p>Competences related to dealing with the content of embedded systems, including their operating systems.</p> <p>Ability to develop joint training modules for trainers and vocational school teachers.</p> <p>Abilities to use the common training clouds of the VET providers and companies.</p> <p>Abilities to manage constant communication and coordination process between the teachers of the vocational colleges and the trainers in the companies.</p> <p>IT competence related to working with databases, cloud services and data security in</p>	<p>Ability to organize the work-based learning in the digitalized workplaces for the students of the initial VET and continuing vocational training.</p> <p>IT skills for trainers and teachers applied in the training process.</p> <p>Ability to create an awareness of the possibilities of modern IT-supported industrial products.</p> <p>Application of didactic approaches that enable students and apprentices to work freely, self-reliably and problem-oriented.</p> <p>Ability to facilitate autonomous development of specific technical skills needed for handling of the different media measures, instruments that in the most cases are learned from experience.</p> <p>Ability to teach the entrepreneurship needed to handle the managerial and organisational tasks in the digitalized and networked workplaces of electronics and mechatronics.</p>	<p>Entrepreneurial skills</p> <p>Communication and cooperation skills applied in the cooperation with human resource management staff in enterprises.</p> <p>Ability to search for information by using Internet and media.</p> <p>Abilities of planning and performing continuous competence development (learning to learn skills).</p> <p>The media competences of trainers and teachers.</p> <p>Soft skills needed for digitalised world, especially the competences of networking and communication.</p> <p>Social skills, stress tolerance, flexibility, the absolute knowledge of the industry, keeping updated, language skills.</p>

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
<p>dealing with company software (SAP and similar) and microcontrollers.</p> <p>To introduce the provision of skills and competences needed to deal with the Internet of Things.</p> <p>Technical competences related to handling with robotics (robot and “cobot”).</p> <p>To program and control production robots in the different technological processes.</p> <p>Competences needed or interactions with sensors, reading information and collecting of data.</p> <p>Abilities to identify the needed work and production processes by applying system vision approaches.</p> <p>Abilities to deal with connected digital programming systems, maintenance and intervention procedures,</p> <p>Quality check and control strategies; skills needed for work with the multifunctional sensors used in the production process.</p> <p>Knowledge management skills in dealing with knowledge of changing work processes.</p> <p>Provision of skills and competencies that enable</p>	<p>Ability to develop practical skills through on-the job-learning.</p> <p>Abilities to develop multi-expertise in the workplaces in real working environments.</p> <p>To use the basic cloud computing solutions in the training process.</p> <p>To develop know-how and skills related to application of LEAN management systems in the supervision of production processes.</p> <p>To train the techniques and approaches of data protection and safe communication of data (protecting commercial secrets) in the production processes.</p> <p>To teach application of the technological solutions for smart work organisation.</p> <p>Ability to adjust the contents of the knowledge fields of ICT software designing, mechanics, electronics to the requirements of the individual work processes from the one side and to the cognitive abilities and specificities of students from the other side in developing modules.</p>	

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
<p>usage and exploitation of sustainable energy and environment friendly technologies in the production processes, as well as provide know-how for responsible and rational use of energy resources in the workplaces. Knowledge on the installation and exploitation of the Internet of Things.</p>		
Competencies needed to deal with changes in the organisation of training process		
<p>Abilities to organize and implement dual training approach. To be able to use a "factory" (also virtual) conceived according to industry 4.0 as a demonstration object. It should be a demonstration of the possibilities that would be as easy as possible for teachers / trainers of different disciplines. To develop an information technology infrastructure for the representation of virtual production processes and automation systems in the training environment. Practicing of the interdisciplinary work. Abilities to work with simulation devices.</p>	<p>To apply the blended learning, integrating theoretical learning in classrooms, on-line learning and practical learning in the real work processes. Training in use of automation systems in the production as well as the use of information and assistance systems combined with the necessary decision-making competence. Supervision and mentorship skills in facilitating learning of other teachers, e.g. in the field of IT skills. Applying didactic approaches that facilitate quick problem solving and decision making. To organize teachers in teams collaborate around a group of students.</p>	<p>Autodidactic continuing learning skills. Accepting that the trainees are superior to teachers in the IT sector.</p>
Competencies needed to deal with changes in the VET didactics.		
<p>To be aware of the opportunities offered by industry 4.0 to have an impact</p>	<p>To apply didactic approaches that promote transversal competences and</p>	<p>Social skills, stress tolerance, flexibility, the absolute knowledge of the industry,</p>

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
<p>on the training and competitiveness of their own company.</p> <p>To prepare exercises with enabling technologies and machines (ex-additive manufacturing).</p> <p>To train working on co-operative robots in the in-company experiences.</p> <p>To enable the student/trainee to interact in the new ecosystems of production, rather than being able to act on a specific machine/product/process.</p> <p>To apply the smartphones as a learning tool in class.</p> <p>To apply the method of case analysis and effective companysimulation.</p> <p>To plan and manage didactical tools for teaching on workplaces in real working environments.</p> <p>To cooperate with companies in setting the teaching plans.</p> <p>To apply the virtual reality in the teaching practice in classroom.</p> <p>To build simulation models in mechatronics area.</p> <p>To work with web-based tasks.</p> <p>To use the different platforms of electronics software programming for training purposes (IBM, Watson,</p>	<p>interdisciplinarity in vocational learning.</p> <p>To evaluate and foresee the learning and competence development potential of students.</p> <p>To apply didactic approaches for development of abstract thinking and wide problem solving competence.</p> <p>To apply weekly projects with different levels of education / education.</p> <p>To organize and implement work based learning in the digitalized and simulated workplaces.</p> <p>To apply the mobile technology enhanced teaching techniques and methods.</p> <p>To exploit the resources of the practical training centres for the organization of training provision.</p> <p>To apply the pedagogical and didactic techniques that foster abilities and skills in shaping and development of the conceptual-practical models related to mechatronics and electronics (that can be adapted and applied for the solution of work tasks and problems).</p> <p>To apply the techniques of demonstration, visualization, examples, playing activities that would enable practical experiencing of the advantages</p>	<p>Keeping updated, language skills,</p> <p>Communication skills, presentation skills, team working skills.</p> <p>Problem solving competence is crucial for teachers and pupils, interdisciplinarity, e.g.</p>

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
SMM service databases).	<p>and advancements of technological changes in mechatronics and electronics.</p> <p>To virtualize the training and learning processes by applying on-line learning with supervision, ensuring direct interpersonal contact between the teacher and student.</p> <p>To reorganize the training process according to the requirements of application of the virtual reality.</p> <p>To apply the pedagogical and didactical techniques that facilitate development of imagination and application of the principles of heuristics in generating new ideas (e.g. experimentation techniques in connecting as many as possible of different equipment and objects to the Internet and getting acquainted with wide range of objects that can be connected to the Internet / testing of as many as possible of different principles, options and ways of connecting things to the Internet and using this networking).</p>	
Competencies needed to deal with changes in the formative assessment of learning outcomes.		
To recognize and assess the competences of learners related to digitalization that they acquire in the informal and non-formal ways.	<p>To identify and evaluate transversal skills.</p> <p>To assess the tacit knowledge and soft skills acquired through learning on the job experiences</p>	Social skills, stress tolerance, flexibility, the absolute knowledge of the industry, keeping updated, language skills, training skills.

Professional/subject related competencies	Didactic – methodical competencies	Transversal and key competencies
<p>To perform simultaneous organisation and running of assessment in electrotechnicalcraftsmanship.</p> <p>To compare the competences provided in VET college and in the training company.</p> <p>To emphasize the "functional" results of the test piece of the practical examination.</p>	<p>or specific training for employability.</p> <p>To improve self-awareness in the student of his own competences.</p> <p>To evaluate the performance of the team of trainees/students.</p> <p>To perform the individualised assessment of competence according to personal study plan with determined objectives and criteria of the section of the curriculum.</p> <p>To perform the formal examination of group work or project work.</p> <p>To perform assessment of individualized, problem-solving work.</p>	

CONCLUSIONS

Research disclosed the following general trends of the implications of the 4th industrial revolution for the work processes of mechatronics and electronics:

- Technological, organisational and societal changes of Industry 4.0 tend to integrate work processes of mechatronics and electronics.
- Shift towards integration of technological processes and related competence needs.
- Still exist some contradiction between scenarios of further generalisation and transversality of work processes from the one side, and increasing specialisation from the other side.
- Difficulties in estimating the implications of work process changes to competence needs.
- Transversality of implications of technological, organisational and societal changes of Industry 4.0.
- Increasing need of solid and systemic knowledge basis.
- Academisation of VET curricula.
- Impact of digital taylorism.
- Transversality of competencies, increasing role of key competencies.
- New competencies referenced to higher levels of qualifications (EQF 5-6).
- Importance of flexibility and permeability of curriculum design.

There have been disclosed the following implications of these changes for vocational education and training:

- Increasing demand of work-based learning and apprenticeship.
- Growing demand of blended, student-centred learning.
- Importance of self-reflection in the training process.
- Increasing role of informal and non-formal learning.
- Individualisation of learning pathways.



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