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Requirements for Education 4.0 and Study Programs within Industry 4.0

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Abstract

In recent years, there has been significant development in the area of implementation of digitization, information systems and new technologies into production. This has led to the emergence of a new industrial revolution, known as Industry 4.0. This revolution will allow for increased labor productivity, with significant changes in the labor market. The requirements for qualifications and skills of employees will increase. This will also affect changes in the education system because the qualification of alumni will be also very important for future smart factory. The qualification of alumni is result of universities study programs that must be alignment with requirements of concept Industry 4.0. For this reason, the main aim of this article is description of requirements for qualification of employees within Industry 4.0 and a description of the study program.

Keywords
Industry 4.0, Education 4.0, Study programs, Human Resources Management, Qualification

1. Introduction

The Industry 4.0 is a very used term today for the new age of intelligent manufacturing. The main vision of this revolution is the emergence of smart factory. [1] In a smart factory, a virtual cyber world will be connected with the world of physical reality. Cyber-physical systems called CPS will be used to connecting machines in the factory. The nine foundational technologies (Autonomous Robots, Augmented Reality, Simulation, Vertical and Horizontal Integration, Cybersecurity, Internet of Things, Big Data, Cloud Computing and Additive Manufacturing) will be a building blocks of this factory. These nine technology trends will transform production into a fully integrated, automated and optimized production flow. [2]

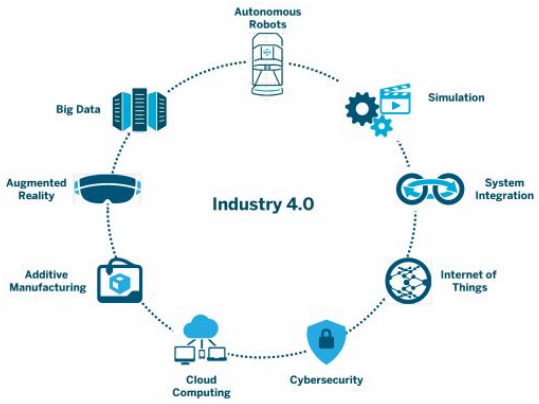

Figure 1. The nine foundational technologies of Industry 4.0 [3]

This industrial revolution will affect not only manufacturing but also the labor market and education. For this reason, Industry 4.0 is considered a cyber-physical-social revolution. [4] Implementation of the concept of Industry 4.0 will allow for increased labor productivity, with significant changes in the labor market. As a result of this implementation some professions and jobs will disappear. Above all, physically demanding and routine jobs will disappear that that will be replaced by robots. On the contrary, new jobs will be created that will be associated with higher demands on knowledge digital technologies and engineering skills. [5] In addition to the normal workload, employees will have to make individual decisions that will be supported by the implementation of new monitoring and optimization systems. Only highly qualified employees will be able to control these new technologies. The qualified employees will become the key to success for the future companies. The competitiveness of companies will depend on highly qualified employees or timely and quality retraining of employees. [6] For this reason, the education framework will be very important part of concept Industry 4.0. This education framework is sometimes also referred to as Education 4.0. [7]

2. State of Art

Education 4.0 also called advanced education is a framework focused on develop skills and build competences for the new era of manufacturing. This education system aims to create a sustainable environment for education of future employees that will aligning with requirements of Industry 4.0. [8] In the Figure 2., there is description of aligning industry requirements with education.

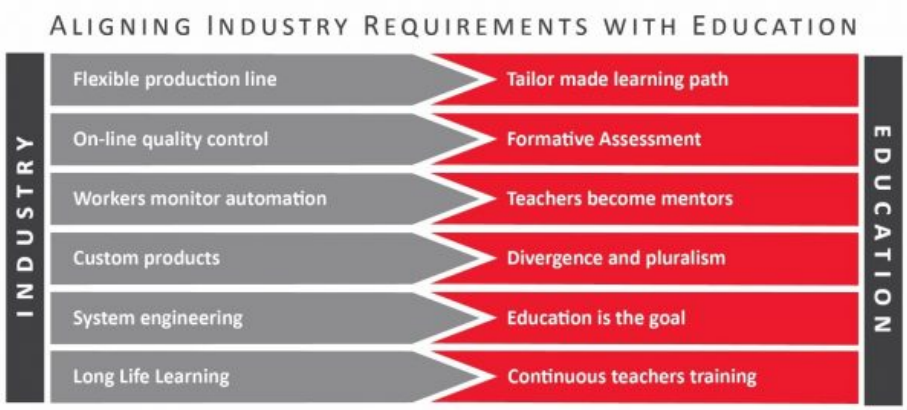

Figure 2. Aligning Industry requirements with education [9]

Industry 4.0 requirements can be summarized as flexibility, increased productivity, individual product manufacturing, knowledge and application of new technologies and manufacturing systems and collaboration with robots. These requirements are essential for the future education system. Institutions try to establish new ways of connecting the theoretical knowledge in with the real cases in smart factories. The Education 4.0 will combine real and virtual world information. The new education tools will be used for teaching such as learning factory. [10] The learning factories are the opportunities and an important way of practicing the technical knowledge and soft skills of students such as complex problem solving. [11] The next tool of Education 4.0 will be a glasses of augmented that will used for training courses of new employees in companies. [12] Very important part of every companies are current employees. These employees will have to take retraining courses. The qualification of current employees could be obtained by the long and expensive company training or by studding in suitable study program at the university and short company training. [13] It follows that the concept of universities study programs for Industry 4.0 has to be founded and the study programs need to be revised due to the Industry 4.0.The entire education system should be set up to align with the concept of Industry 4.0. The main aim of this article is created of education framework that should include not only a description of the necessary professions for Industry 4.0 and the requirements for these professions, but also a description of the study program.

3. Research Methodology

The following techniques were used to determine the necessary professions and their qualifications and skills as well as study program:

- Literary research

  The literary research includes current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. The literary research was used to findings the current result of other research and to find out the unexamined areas of the topic.

- Interview

The interview methodology is a conversation where questions are asked and answers are given. The interview was used in our case. In this technique, information of vision and impacts of Industry 4.0, requirements for qualification and skills of employees were collected from the experts.

- Brainstorming

Brainstorming was another methodology that was used for description of study program "Process Management of Industry 4.0". In this technique, the group of experts meet to generate new ideas and solutions (in our case the risks identification) around a specific domain of interest by removing inhibitions. People are able to think more freely and they suggest many spontaneous new ideas. All the ideas are noted down, those ideas are not criticized, and after brainstorming session, the ideas are evaluated.

4. Requirements for Employees of Industry 4.0

The new industrial revolution will have an impact on the labor market. From employees will be required to have higher qualifications, especially in field of engineering and information technologies. With higher qualification requirements, so-called soft skills will also increase. These soft skills will become more and more important than currently. Because employees will be forced to solve new production problems and independently decide on further steps. This will also increase employee responsibility for production processes of smart factories.

4.1 Required skills of employees

Skill can be defined such as learning-based disposition for proper, fast and cost-effective performance of a particular activity. Skills can often be divided into domain-general and domain-specific skills. In psychology, especially in management-oriented disciplines, skills are also divided on so-called soft and hard skills. Hard skills are easily quantifiable unlike soft skills and can be verify by the test. Hard skills also called technical skills are a set of professional requirements (theoretical knowledge, practical skills) needed to pursue a profession. Soft skills are a combination of interpersonal people skills, social and communication skills. The level of these skills cannot be unequivocally quantifiable. [14]

As a result of implementation Industry 4.0, employees will be required to have specific hard and soft skills. Because employees of smart factory will be able to control new technologies and also decide independently and solve various production problems. A complex problem solving, critical thinking, coordination with others and creativity are the most important required new skills according to the World Economic Forum. [15] A "knowledge worker" is a new term for an employee who will have these new required skills together with digital skills. [16] For this reason, the required skills of employees of smart factory are described in Table 1. These skills should be taken into account when developing new degree programs.

Table 1. Division into soft and hard skills required of Industry 4.0

Hard skills	Soft Skills
Language knowledge	Communication skills
Degrees, apprenticeships, certificates with technical or information focus	Flexibility
Machine operation	Self-discipline
Programming language	People Management
Software knowledge	Time Management
Cybersecurity knowledge	Emotional Intelligence
Knowledge of Data Analysis	Critical Thinking
Cloud Computing	Creativity
Knowledge of Artificial Intelligence	Coordination with others
Knowledge of Processes	Complex Problem Solving

4.2 Required job position and qualification

The impact of automation and digitization will inevitably lead to a reduction in low-skilled jobs. On the contrary, the demand for graduates of technical schools with education in information technologies and data analysis will increase. In particular, the following jobs will be necessary for a smart factory, as described in Tables 1 and 2. The job positions needed for the Industry 4.0 were founded in our previous research. These job profiles were determined using individual implementation phases of Industry 4.0. For each of the following professions, the necessary qualifications and hard and soft skills are description.

Table 2. Description of required qualification and skills of professions of information technologies

	Qualification	Hard Skills	Soft Skills
Informatics Specialist	Secondary / Postgraduate education in IT Practice on a similar position	Language skills - English, Germen etc.; Analytical/Logic thinking; Advanced knowledge of large domain and network management; Basic knowledge of working with databases, virtualization and cloud services	Autonomy; Responsibility; Creativity; Flexibility Communication skills; Reliability People Management; Time Management; Problem solving
Robot Programmer	Secondary / post graduate education focused on automation technology Practice on a similar position	Language skills - English, Germen etc.; Analytical/Logic thinking; Knowledge of the simulate process; Knowledge of off-line and on-line robot programming; Experience with basic robot parameterization and calibration	Responsibility; Flexibility; Creativity; Communicativeness Reliability; Problem solving; Cooperation with others
Software Engineer	Secondary / postgraduate education in IT	Language skills - English, German etc. ; "Knowledge of C/C++ programming; Knowledge of C # / .NET"; Basic knowledge of working with databases (SQL)	Autonomy; Creativity; Flexibility; Problem solving; Cooperation with others

Data Analyst	Secondary / postgraduate education in technical or mathematical / statistical direction	Language skills - English, German etc.; Analytical/Logic thinking; Knowledge of working with a spreadsheet (Excel); Basic knowledge statistically; PL / SQL – advanced; UML - advanced	Autonomy; Creativity; Flexibility; Problem solving; Cooperation with others; Time Management;
Cybersecurity	Secondary / postgraduate education in IT	Language skills – English, German etc; Analytical/Logic thinking; Knowledge of security standards and communication standards; Knowledge of servers (level - administrator)	Autonomy; Responsibility; Creativity; Cooperation with others; Ability and willingness to learn new things; People Management;

Table 3. Description of required qualification and skills of production professions

	Qualification	**Hard skills**	**Soft skills**
Electronics Technician	High school education focused on mechanical Practice in the field of handling technology and industrial equipment	Knowledge of maintenance new machines; Knowledge of service of the pressure cylinders; Knowledge of performing service inspections; Analytical/ Logical thinking;	Manual skills; Flexibility; Autonomy; Responsibility; Creativity; Complex Problem Solving;
Automation Technician	High school education in electrical engineering /automatization Practice and experience of machine maintenance and automated lines	Knowledge of safety standards Language skills - English, German etc.; Analytical/ Logical thinking;	Manual skills; Flexibility; Autonomy; Responsibility; Creativity; Complex Problem Solving;
Production Technician	High school education in electrical engineering	Language skills - English, German etc.; Analytical/ Logical thinking;	Flexibility; Creativity; Complex Problem Solving; Creativity; Autonomy; Responsibility; People Management; Time Management; Cooperation with others; Ability and willingness to learn new things;
Manufacturing Engineer	Secondary / postgraduate education in electrical engineering	Technical skills; Language skills - English, German etc. Knowledge of technical documentation; Analytical/ Logical thinking;	Flexibility; Complex Problem Solving; Autonomy; Responsibility; Creativity; Cooperation with others; Communication skills; People Management; Time Management;

5. Study program for Industry 4.0

Individual study programs can be created on the basis of established professions and the necessary qualifications and skills from the Table 2. and Table 3. Individual study programs for each profession are better because graduates have more knowledge of the field, but the disadvantage is that they are specialized only on the problematics and issues of this field. Or it is possible created the single study program for information technologies with data analysis, study program of process management and study program of Automation technician and Robot Programmer. All study programs should be divided into bachelor's and master's degree programs.

In this article the bachelor´s study program "Process Management of Industry 4.0" will be described. The aim of this study program is to introduce and prepare students for a new industrial revolution called Industry 4.0. Graduates of this program could be employed in a position of Production Technician or Manufacturing Engineer. This Bachelor's degree program should be for three years. The graduate of the "Process Management of Industry 4.0" program will acquire the basic theoretical knowledge necessary for the design, manage and optimization of industrial production processes in the smart factory. The student would be familiar with the basic technologies needed for a smart factory (Autonomous Robots, Augmented Reality, Simulation, Vertical and Horizontal Integration, Cybersecurity, Internet of Things, Big Data, Cloud Computing and Additive Manufacturing) and basic knowledge of electrical engineering. The graduate of the program would be able to make independent decisions and solve problems in production. To achieve this, not only practical exercises with individual technologies but also learning factories were included in the lessons. Within these learning factories, students would practically try to simulate various problems in production, which they would then solve and thus be able to improve their soft skills. Subjects of study program "Process Management of Industry 4.0" are described in the Table 4.

Table 4. Basic subjects of Bachelor´s study program of "Process Management of Industry 4.0"

The Title of the Subject	Lectures	Exercises	Final examination
Mathematics 1	2	1	Combination (Credit, Exam)
Mathematics 2	2	1	Combination (Credit, Exam)
Statistics	1	1	Credit
Theoretical Electrical Engineering 1	2	2	Combination (Credit, Exam)
Theoretical Electrical Engineering 2	2	2	Combination (Credit, Exam)
Electric machines	2	1	Combination (Credit, Exam)
Microelectronics	2	1	Combination (Credit, Exam)
Printed electronics	2	1	Combination (Credit, Exam)
Materials and Additive technologies	2	2	Combination (Credit, Exam)
Artificial Intelligence	2	1	Combination (Credit, Exam)
Computer support and networks	2	2	Combination (Credit, Exam)
Smart Technologies and Internet of Things (IoT)	2	2	Combination (Credit, Exam)
Cloud Computing	2	2	Combination (Credit, Exam)
Cybersecurity	2	2	Combination (Credit, Exam)
Law and data security	2	0	Credit

Data analysis	2	2	Combination (Credit, Exam)
Augmented and Virtual reality	2	2	Combination (Credit, Exam)
Simulation of production processes (use of learning factory)	0	4	Credit
Process control techniques	2	2	Combination (Credit, Exam)
Business in Industry 4.0	2	2	Combination (Credit, Exam)
Quality management in production	2	2	Combination (Credit, Exam)
Foreign language	0	2	Credit
Practice in the company	0	8	Credit
Bachelor thesis	0	0	Credit

6. Conclusion

Industry 4.0 is currently a widely used and widespread term for the concept of new industrial revolution that has arisen as a result of the development and implementation of new technologies into production. The basis of a smart factory will be digitization and the following nine technologies – Autonomous robots, Simulation, System Integration, Internet of Things (IoT), Cybersecurity, Cloud Computing, Additive Manufacturing, Augmented Reality and Big Data. Implementation of these new technologies will have an impact on employee qualifications. Only highly qualified employees will be able to control these new technologies. The qualified employees will become the key to success for the future companies. For this reason, the education framework will be very important part of concept Industry 4.0. The main aim of this article was created of education framework that should include description of the necessary professions for Industry 4.0 and study program.

In the first part of the article there is a description of necessary professions for Industry 4.0. The job positions needed for the Industry 4.0 were founded in our previous research. These job positions are for example Electronics Technician, Automation Technician, Production Technician, Manufacturing Engineer, Informatics Specialist, Robot Programmer, Software Engineer, Data Analyst or Cybersecurity Specialist. These job profiles were determined using individual implementation phases of Industry 4.0. The description of these professions has been extended with the necessary soft and hard skills. In the next part, the bachelor´s study program "Process Management of Industry 4.0" will be described. Twenty-four courses were set for the study program. On the basis of literary research and interview with experts, 24 subjects for the given study program were set. For each subject, the number of lectures and exercises required to acquire and verify knowledge was chosen.

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Biographies

Andrea Benešová

In 2013 obtained bachelor degree in Commercial Electrical Engineering at the University of West Bohemia in Pilsen. In 2015 obtained master degree in Commercial Electrical Engineering at the University of West Bohemia in Pilsen, diploma thesis "Analysis and modeling of selected processes in electrical engineering production ". From 2015 to present she is a Ph.D student at the University of West Bohemia in Pilsen, Faculty of Electrical Engineering, Department of Technologies and Measurement, topic of her doctoral thesis is "Management of prospective technological processes in electrical engineering". She has published conference papers such as Requirements for Education and Qualification of People in Industry 4.0.

Ing. Martin Hirman, Ph.D.

Martin Hirman was born in 1989 in Pilsen, Czech Republic. In 2008 he graduated at the Secondary School of Electrical Engineering in Pilsen. In 2011 he obtained bachelors degree in Commercial Electrical Engineering at University of West Bohemia in Pilsen. In 2013 he obtained masters degree in Commercial Electrical Engineering at University of West Bohemia in Pilsen, diploma thesis "Optimization stock processes". In 2017 he obtained doctors (Ph.D.) degree at University of West Bohemia in Pilsen, Faculty of Eletrical Engineering, Department of Technologies and Measurement. The topic of his dissertation was "Material and process aspects of components connecting to flexible substrates". Currently he is a member of the Regional Inovation Centre of Electrical Engineering and of the Department of Technologies and Measurement.

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Frantisek Steiner was born in Rokycany in 1973. He was awarded an Ing. (MSc) degree in the field of Applied Electronics in 1996, a PhD degree in the field of Electronics in 2001 and an Associate Professorship in Electrical Engineering in 2008. He is an Associate Professor at the Faculty of Electrical Engineering of the University of West Bohemia. He is the head of the Diagnostics and Testing Engineering Team at The Regional Innovation Centre for Electrical Engineering (RICE). His research fields include diagnostics of electronic assemblies, soldering, replacement of lead-based solder and intermetallic compounds. He has published more than 115 papers and presented 40 contributions in 35 congresses.

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J. Tupa received his MSc (2002) and PhD (2006) in Electrical Engineering from Faculty of Electrical Engineering, University of West Bohemia in Pilsen in Czech Republic. He is a Vice-dean of faculty and Senior Lecturer at Department of Technologies and Measurement. Dr. Tupa is member of executive management at Regional Innovation Centre for Electrical Engineering of the Faculty of Electrical Engineering at the University of West Bohemia in Pilsen. He is also PhD supervisor, reviewer of journal and conference publications and co-organizer of conferences. His research interests include Business Process Management, Quality Management, Risk and Performance Management in Electrical Engineering Industry, Industrial Engineering, Electronics Manufacturing and Diagnostics, Financial and Project Management, Copyrights and patents law, information law and transfer of IPR. Jiri Tupa is responsible for several international research and development projects with industrial and University partners. The project RiMaCon - Risk Management Software System for SMEs in the Construction Industry is one of the important international projects. This project has received funding from the European Union's Seventh Framework Program for research; technological development and demonstration (2013-2017). The RiMaCon project's main goal is to implement a collaborative effort to promote the sharing of knowledge and competencies in a long-term strategic research partnership around the development, testing and validation of a cost effective and user-friendly risk management system for SMEs in the construction sector.