Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 11 (2017) 2195 – 2202

Procedia MANUFACTURING

27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27-30 June 2017, Modena, Italy

Requirements for Education and Qualification of People in Industry 4.0

Andrea Benešová[a]*, Jiří Tupa[a]

[a] *Department of Technologies and Measurement, University of West Bohemia in Pilsen Univerzitni 8, CZ 306 14 Pilsen, Czech Republic*

Abstract

The vision of Industry 4.0 will be bring not only new approaches but also the methodologies and technologies, which will have to be introduced into companies. The transition to such a sophisticated production will not be possible immediately. The main reasons are high financial costs and the lack of qualified employees. This article deals with identification of job roles in the companies.

Keywords: Education 4.0, Industry 4.0, Human Resources Management, Smart Factory, Qualification

1. Introduction

In the past, the industry was affected by technological change and innovation. These paradigms are called industrial revolutions. These revolutions were caused by mechanization (1st industrial revolution), use of electrical energy (2nd industial revolution) and electronics and automation (3rd industial revolution). [1] All these industrial revolutions did not influence only the production itself, but also the labor market and the educational system as well. As a result of these changes some professions and jobs disappeared. Currently, due to the development of digitalization and robotics, we are facing the next industrial revolution, known as the Industry 4.0. It is expected that

* Corresponding author.
E-mail address: benesov2@ket.zcu.cz

doi:10.1016/j.promfg.2017.07.366

some professions will be replaced. The emerging technologies have huge effect on the education of people. Only qualified and highly educated employees will be able to control these technologies. The industry should collaborate with universities. [2] The main vision the following of Industry 4.0 is the emergence of "smart factories", that will be connected to the production facilities Cyber-physical systems called CPS. [3] Using of the Internet of Things, the Internet of Services and the Internet of People will make connection: machine-machine, human-machine or human-human, and at the same time an enormous amount of data will be obtained. For this reason it will be necessary to analyze large data (Big Data) to be able to predict possible failures and adapt in real time to the changed conditions. [4] Currently, the human is an operator of machines and these machines only passively follow the operator´s commands. The main trend of Industry 4.0 will therefore replace this condition by the Prognostics-monitoring system. [5] Production processes will have to allow effective production and at the same time be flexible due to the changing customer demand for particular products. For this reason the companies will produce smart products. [6] The timely analysis of the obtained data is important for planning and managing of the flexible production. The obtained data can contain classified information and this leads to increased demands on cyber security to prevent leaks of any data.

The role of the human factor will be necessary for the future manifacturing. The skills and qualifications of the workforce will become the key to success of a highly innovative factory. [7] For this reason, the companies should be focused on the development of qualified workforce by the Human Resources Management. [8] The Human Resources Management is not only focused on selection, staffing and dismissing employees but also on human resource development, i.e. education, learning and training of employees. [9] According to Hecklau et all., it is possible to aggregate and categorize competencies into four main groups – Technical, Methodological, Social and Personal competencies. [10] Requirements for the qualifications and skills of employees will be higher than at present, because the companies will use new technologies and smart media. For this reason the education system will be changed from Education 3.0 to Education 4.0. [11] Education 4.0 will combine real and virtual world information. Virtual resources, for example glasses for virtual reality, will be used for teaching. [12] Higher education will be enhanced, for example the course of information science will need to include knowledge about processes management. [13] The knowledge, qualification framework and staff training will be an essential part of Industry 4.0. [14] Virtual learning environments (VLEs) will be used for high transfer of developed knowledge and skills. Teachers and students will meet with their avatars in the VLEs. [15,16] VLE will be the first step in the education of new employees. The next part of education will be the implementation of augmented reality in the real environment. In this part, the training courses of new employees will be realized through the glasses of augmented reality. [17,18] These types of education are very costly, This fact can lead to the privatisation of some institutions of higher education or that establishing high schools by big companies. [19]

2. Implementation phase of industry 4.0

It is important to realize that 4.0 implementation in industrial enterprises can not be done abruptly, but rather it is a gradual change. If we focus on the implementation of Industry 4.0 to the small and medium-sized enterprises, it is necessary to make this change in the several phases. For example, the AIMTEC company distributes industry 4.0 implementation to four basic phases. In Figure 1 various phases are described.

On the basis of the various stages of implementation of Industry 4.0, as shown in Figure 1, it would be possible to determine the required jobs. It is presumed that small and middle enterprises implemented a basic information system in the past. This information system allows at least: bookkeeping, some human resources administration and displaying of some basic business indicators that are used for enterprise management. If a similar information system is missing in a specific enterprise, this enterprise has to implement a zero phase. The zero phase is about implementing of some basics of an advanced information system, which is the entry point of industry 4.0.

Implementation of the zero phase will uncover some problems. The biggest ones will be inadequate computer skills and the age of employees. These two factors are critical for all the phases of Industry 4.0.

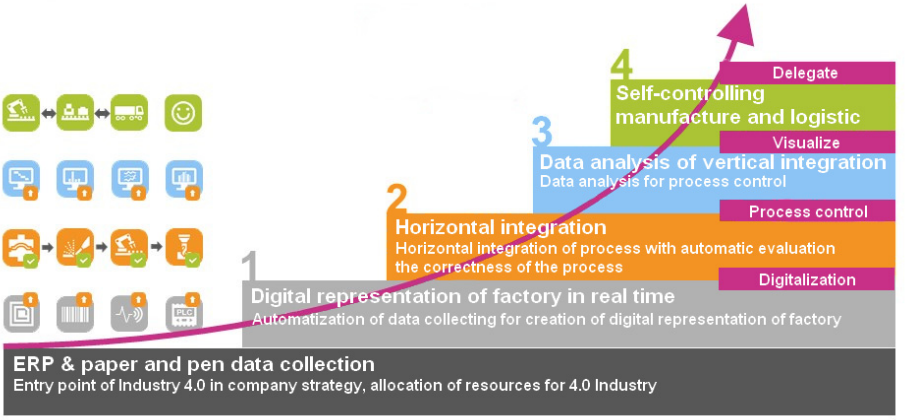

Fig.1. Implementation phase by AIMTEC, a.s. company [20]

2.1. First phase – digital representation of factory in real time

The first phase will consist of introducing a fully-fledged information system such as ERP / ERP II. This phase will of course be carried out by companies that have so far implemented a similar information system. The introduction of an information system in the company causes the mapping of all processes. For this reason, the companies need process engineers who are experienced and knowledgeable in the areas of the mapping process. Process engineers will be needed even in the second phase of the implementation. In addition to mapping of all processes, it will be also necessary to digitize all the data and to record the data that were not previously recorded. The data model of the company in the information system must correspond with the reality. At this stage, the company will increase the volume of the retained and stored data. These data, however, will be important for the next phase of the transition to the vision of Industry 4.0.

The increasing volume of data will also increase the demand for the cloud system and services. So in this branch of IT, it will increase the demand for specialists for the implementation of the cloud system and services. The cloud system engineers and integrators will be required. After switching to the cloud systems, this IT employee will get a new role. They will not be responsible for the maintenance of the server hardware and software but they will support users in the new systems. Of course, they will still have the responsibility for the functioning of the whole IT equipment in the company, but the responsibility for the server hardware and the system accessibility will be on the cloud system provider.

2.2. Second phase – Horizontal integration

The second phase will implement new automated machines. These new machines will lead to reengineering of the production process. So this part will again require process engineers. They can be company employees who undergo a retraining course for the new automated machines. Therefore, some manufacturing workers can become

process engineers with relevant education. This approach is a good investment, because the current employee knows the company and the current company processes.

As mentioned before, with this step, the new machines will come. All current workers will need some kind of retraining. There are two types of ways. Complete retraining of all the employees by supplier, or very special training of one employee, who then may retrain an other employee and will be the expert in these machines in the company. These retrained employees will manage operating the machinery. Companies will also have technicians, who will be able to re-deploy these machines in the case of minor defects.

For the success of any company, it is important to satisfy the customer needs which are constantly changing. Constantly changing customer needs affect the demand in the market. This phenomenon has an impact on the flexibility of companies. If a company is flexible, it is possible to fulfill more customer needs. Customer requirements will affect not only the flexibility of companies, but also the variability of manufactured products. Automation of the basic production will result in a rapid decrease in the number of people, who are required to the basic production. Products will vary according to customer requirements. Thus, companies would avoid losing their employees because it will cause only a change in their job.

The new automated machines will have to telemetric and diagnostic unit, which can be connected to the network and the data can be collected and analyzed. This data will be also important for the whole vision of Industry 4.0.

2.3. Third phase – Data analysis of vertical integration

In the third phase data from the first and second phase will be used. In this phase, sophisticated methods for data processing will be deployed. And here we will find the biggest problem of Industry of 4.0. Education systems did not predict the rapid demand for data analysts, so the data analysis as a field of study is very small and underdeveloped at this time. In this case it is not possible to use existing employees and improve their skills by retraining, because data analysis is a very complicated and comprehensive field of study. The secondary problem is that we will not look for any data analysts, we will need data analysts who are knowledgeable in the specific field. Of course, we will need some business intelligence data analytics, so we will need business data analyst. But this job can be outsourced, if we talk about small and medium enterprises.

In the case of small enterprises the main demand will be focused on data analysts who will have knowledge of data analysis, but also of the production process. The reason for this requirement is to delegate the production process to these data analysts and also for financial reasons. In large enterprises there will have to be a link between the individual departments, to have a properly controlled production process, for example IT departments will have to cooperate with the process engineers and quality controllers. If the departments do not collaborate, it can lead to data evaluation that will not have any impact on the process.

2.4. Fourth phase – Self controlling manufacture and logistic

In the fourth phase we will get an almost autonomous manufacturing. We will only need operators, maintenance workers and data analysts, process engineers, quality controllers etc. The manufacturing process will be self-optimizing, so the productivity will be maximal. For optimal delegation of production and accelerating solutions of various problems it will become necessary for employees to have sufficient language knowledge as it may happen that mutual communication will be required in large companies that have factories all over the world. Of course, it is the essential part of the company's logistics department, which is responsible for managing transport and storage

activities of the organization, which includes the management of material and information and financial flows in order to satisfy customer requirements.

When we look at the whole picture of retraining and changing roles we can say that the first two phases will be difficult for the company employees. It will be caused by implementing new IT systems and services. Companies will have to exert maximum effort to help employees improve their skills and knowledge.

3. Qualification and skills for Industry 4.0

Table 1. IT job profiles

	Qualification	Skills
Informatics Specialist	Secondary / postgraduate education in IT Practice on a similar position Advanced knowledge of large domain and network management Basic knowledge of working with databases, virtualization and cloud services	Language skills - English, German etc. Autonomy; Responsibility; Flexibility Communicativeness Reliability Ability to plan, lead a small team, organizational skills; Problem solving
PLC Programmer	Secondary school education focused on electrical engineering Practice Proven experience in programming of machinery Programming and knowledge of PLC	Language skills - English, German etc. Knowledge of working with Beckhoff TwinCAT Responsibility; Flexibility; Communicativeness Reliability; Ability and willingness to learn new things
Robot Programmer	Knowledge of off-line and on-line robot programming Experience with basic robot parameterization and calibration Project management, co-ordination of the robot programmer team and coordination with PLC programmers Secondary / post graduate education focused on automation technology Installation of the device into operation	Language skills - English, German etc. Analytical/Logic thinking Responsibility Flexibility Communicativeness Reliability Knowledge of the simulate process; Problem solving
Software Engineer	Secondary / postgraduate education in IT; "Knowledge of C/C++ programming; Knowledge of C # / .NET"; Practice; Basic knowledge of working with databases (SQL)	Language skills - English, German etc. Autonomy; Creativity; Flexibility Analytical/Logic thinking; Problem solving;
Data Analyst	Secondary / postgraduate education in technical or mathematical / statistical direction PL / SQL – advanced UML - advanced	Language skills - English, German etc.; Autonomy; Creativity; Flexibility; Analytical/Logic thinking Knowledge of working with a spreadsheet (Excel) Basic knowledge statistically; Problem solving
Cyber security	Secondary / postgraduate education in IT	Language skills – English Autonomy; Responsibility; Creativity; Cooperation Ability and willingness to learn new things Analytical/Logic thinking Knowledge of security standards and communication standards Knowledge of servers (level - administrator)

Table 1 describes qualifications and skills needed for Information Technology (IT) job profile. All these IT job roles will require knowledge of the processes for correct data processing. Informatics Specialists will manage a small team of IT technicians. Such teams will provide individual support processes, such as network infrastructure or maintenance of server systems. Another important job is that of a PLC Programmer because he provides basic,

complementary automation and the development of automated systems. One of the industry's 4.0 goals is to remove heavy physical labor by industrial robots. Dynamic use of industrial robots requires programming and commissioning. These activities are performed by the Robot Programmer. Information systems are also important to ensure the flexibility of the production process. These systems are developed, edited and distributed by software engineers. Information systems and databases store valuable information, important for optimizing production and business management. This information is processed by data analysts based on data analyses. An important factor for Industry 4.0 will be data security and data communications. The reason is a competitive struggle that will not only be on the market but also outside. There may be hacker attacks on information and production systems. These systems will be secured by cyber security technicians.

Table 2 indicates qualifications and skills needed for the production job role. The Electronics Technician is the first job profile and his responsibility is machine maintenance. He is supposed to have manual skills and some basic knowledge of electrics and hydraulics. Automated production requires, in addition to PLCs, actuators and mechanical parts. The design and installation of these mechanical parts are provided by the Automation Technician. In automated production humans will be still needed, they will be in charge of control and supplies. This job profile is called Production Technician. Even though Industry 4.0 is to be fully automated, process engineers will still need to control and oversee the improvement of the automated process. Process engineers will be involved in analyzing causes of errors and performs the product quality control at the output. Controlling the final product will be important for further optimization and setting of the process.

Table 2. Production job profiles

	Qualification	Skills
Electronics Technician	High school education focused on mechanical Practice in the field of handling technology and industrial equipment Performing service inspections	Manual skills Ability to learn how to maintain new machines Flexibility; Autonomy; Responsibility Basic knowledge of electronics, hydraulics Service of the pressure cylinders
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. Flexibility; Autonomy; Responsibility
Production Technician	High school education in electrical engineering	Language skills - English, German etc. Logical thinking Flexibility Autonomy Responsibility Ability and willingness to learn new things; Media skills
Manufacturing Engineer	Secondary / postgraduate education in electrical engineering	Technical skills; Language skills - English, German etc. Autonomy; Responsibility; Creativity Knowledge of technical documentation Ability and willingness to learn new things Organizational skills; Cooperation; Media skills, Communication skills

4. Conclusion

It is important that in the first step the companies correctly identify in which of the aforementioned implementation phases are currently find themselves. Furthermore, companies will have to have a vision for the future manufacturing processes and to manage them. Based on these assumptions, the change of the manufacturing processes should be carried out gradually rather than abruptly. During this gradual change, various job positions will

disappear and some will be newly created. The main reason for retaining existing employees is their knowledge of the current manufacturing process. If you look at the individual stages in terms of education and qualifications, it can be assumed that the early days of retraining and qualifications will be problematic. In the last two stages, however, there will be a need for educated and skilled workers in the field of computing, self-learning algorithms and data analysis.

This results in the creation of new, and changing the existing curricula and disciplines within tertiary education. In the beginning, therefore, there will be a lack of programmers and data analysts. In terms of the structure of the company, significant changes are unlikely, but of course, it depends on the structure of the respective companies. In terms of jobs, companies will mainly face extinction of physically demanding positions. These will be replaced by automated machines for the production, requiring personnel conducting the operation, maintenance and, where appropriate, restoration of the facilities in case of obsolescence of certain parts. The existing staff will have to take part in retraining programs.

The company will focus on the implementation of project activities of employees in the first place. This means that for example, the data analyst will not only address processing of production data, but he will also be involved in projects aimed at optimizing the satisfaction of customers and other short-term projects.

Acknowledgements

This research has been supported by the Ministry of Education, Youth and Sports of the Czech Republic under the RICE – New Technologies and Concepts for Smart Industrial Systems, project No. LO1607 and by the Student Grant Agency of the University of West Bohemia in Pilsen, grant No. SGS-2015-020 "Technology and Materials Systems in Electrical Engineering".

References

[1] Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. Industry 4.0. *Business & Information Systems Engineering 2014*;6: 239-242. DOI:10.1007/s12599-014-0334-4

[2] Baygin M., Yetis H., Karakose M., Akin E. An Effect Analysis of Industry 4.0 to Higher Education. 15th International Conference on Information Technology Based Higher Education and Training (ITHET) 2016; 1-4. DOI: 10.1109/ITHET.2016.7760744

[3] Lee J. A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems A Cyber-Physical Systems architecture for Industry, Society of Manufacturing Engineers 2014 ; 3: 18–23. DOI: 10.1016/j.mfglet.2014.12.001

[4] Richert A., Shehadeh M., Plumanns L., Schuster K., Jeschke S. Educating Engineers for Industry 4.0: Virtual Worlds and Human-Robot-Teams Empirical Studies towards a new educational age, IEEE Global Engineering Education Conference (EDUCON), Abu Dhabi, 2016 ;142-149. DOI: 10.1109/EDUCON.2016.7474545

[5] Lee J., Kao H., Yang S. Service innovation and smart analytics for Industry 4.0. and big data environment. Procedia CIRP 2014; 6: 3-8. DOI: 10.1016/j.procir.2014.02.001

[6] Nelles J., Kuz S.,Mertens A., .Schlick C.M. Human-centered design of assistance systems for production planning and control. IEEE International Conference on Industrial Technology (ICIT), Taipei, 2016; 2099-2104. DOI: 10.1109/ICIT.2016.7475093

[7] Gehrke L, Kühn AT, Rule D, Moore P, Bellmann C, Siemes S, et al. A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective. Düsseldorf; 2015

[8] Armstrong M., Taylor S. Armstrong's Handbook of Human Resource Management Practice. 13th ed. London: Kogan Page; 2014. ISBN: 978 0 7494 6964 1

[9] Becker M. Personalentwicklung - Bildung, Förderung und Organisationsentwicklung in Theorie und Praxis. 6th ed. Stuttgart: Schäffer-Poeschel; 2013. ISBN: 9783791032436

[10] Hecklau F., Galeitzke M., Flachs S., Kohl H. Holistic Approach for Human Resource Management in Industry 4.0. Procedia CIRP 2016; 54: 1–6. DOI: 10.1016/j.procir.2016.05.102

[11] Harkins A. M. "Leapfrog Principles and Practices: Core Components of Education 3.0 and 4.0. Leapfrog Principles and Practices. Futures Research Quarterly draft VIII, 2008;1–15.

[12]Katharina M., Dominic G. IN-FACTORY LEARNING-QUALIFICATION FOR THE ACTORY OF THE FUTURE. ACTA UNIVERSITATIS CIBINIENSIS – TECHNICAL SERIES 2015; LXVI:159-164. DOI: 10.1515/aucts-2015-0046

[13] Pfeiffer S. Effects of Industry 4.0 on vocational education and training. Institute of Technology Assessment (ITA) 2015. ISSN-online: 1818-6556
[14] Huba M., Kozák Š. F. From E-learning to Industry 4.0. International Conference on Emerging eLearning Technologies and Applications (ICETA), Vysoke Tatry, 2016;103-108. DOI: 10.1109/ICETA.2016.7802083
[15] Richter A. et all. LEARNING 4.0 : VIRTUAL IMMERSIVE ENGINEERING EDUCATION. International Best Practices and Applications 2015;11:51–66.
[16] Schuster K. Preparing for Industry 4.0 – Testing Collaborative Virtual Learning Environments with Students and Professional Trainers. International Journal of Advanced Corporate Learning 2015;8. DOI: 10.3991/ijac.v8i4.4911
[17] Devedzic G., Bari P. Engineering Design Education for Industry 4.0: Implementation of Augmented Reality Concept in Teaching CAD Courses. International Conference on Augmented Reality for Technical Entrepreneurs (ARTE'16) 2016.
[18] Rüßmann M. et all. Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. 2015.
[19] Störmer E, Patscha C, Prendergast J, Daheim C, Rhisiart M, Glover P, Beck H. The Future of Work: Jobs and skills in 2030; 2014.
[20]AIMTEC a.s., "Digitalizace společností – průmysl 4.0" [online] ©2016.AIMTEC [cit. 03.03.2017] Available from: http://www.aimtec.cz/reseni/digitalizace-spolecnosti-prumysl-4-0/