Analysis of Human Skills in Industry 4.0

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***Abstract*—This paper presents a state-of-the-art of recent research work analyzing the requirements of Industry 4.0, particularly related to the competences issue. Over the last few years, the fourth industrial revolution has attracted researchers worldwide to find suitable solutions. However, there are still many gaps related to the Industry 4.0, particularly related to the humans competences issue. Among the many challenges facing companies in this paradigm, one of the most important is the qualification of employees with the necessary skills to succeed in a transformed work environment. To cope with knowledge and competence challenges related to new technologies and processes of Industry 4.0, new strategic approaches for holistic human resource management are needed in manufacturing companies. The main objective of the presented research is to investigate the importance of employee competences, key to the development of Industry 4.0.**

Keywords-Human Competences; Skills; Industry 4.0; human resource management; Fourth Industrial revolution.

I. INTRODUCTION

In industrial companies that are subject to constant competitive pressure [4], changes are coming faster and are more unpredictable [5]. This has considerable consequences on their investments and their competitiveness, which are highly dependent on knowledge, skills, competences and creativity of its workforce. Today, we are on the cusp of the Fourth Industrial Revolution [35], or Industry 4.0, expected to deeply change the future manufacturing and production processes, and which leads to smart factories and networked industrial environments that will benefit from its main design principles. The adoption of new technologies and production processes undoubtedly implies more qualified workforce. Thus, the biggest challenge for industrials would be to adapt their workforce to be able to follow the current revolution. Fig.1 [8] provides a global view of enabling technologies for Industry 4.0 and the organizational requirements in terms of technical and management problems for successful implementation. In recent years researchers have been very interested in Industry 4.0 and have published a large number of works in this field. Some works focused on the challenges that companies face in qualifying employees with the necessary skills, while others emphasize new learning approaches to adapting Engineering Education to Industry 4.0 Vision,

Certain researchers are particularly interested in specific modules to integrate them into teaching programs and adapt

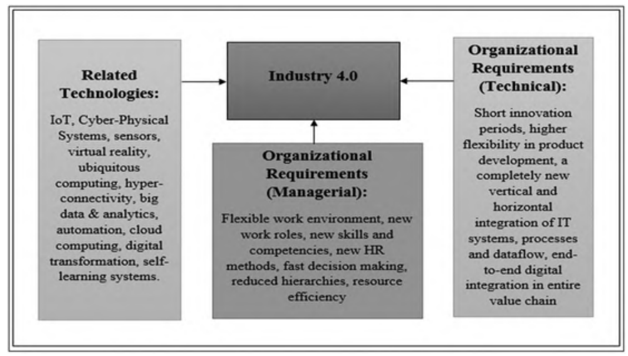

Figure 1. Overview of Industry 4.0

them to Industry 4.0. By contrast, other articles are also focused on the transformation of education itself according to the needs of Industry 4.0. Finally, a sequence of works demonstrates new concepts of learning factories and responds to the growing demand of future skills of production staff and laboratories to allow students to discover production environments type 4.0.

In Section 2, we will discuss the challenges and new technologies facing business workers in Industry 4.0. Section 3 presents the required competencies in Industry 4.0. Section 4 finds the challenges facing the new technologies to respond to Industry 4.0 requirements. Section 5 illustrates the role of training in the formation of Industry 4.0 skills. Section 6 explains the requirement of skills approach and finally, Section 7 concludes the paper.

II. THE ISSUES AND CHALLENGES RELATED TO SKILLS FACE INDUSTRY 4.0

In a globalized world with highly interconnected processes, companies are faced with an increasing number of challenges to be met [1], especially in terms of adapting their skills to the automation and digitalization in progress. In this context, research work of great importance and surveys have been carried out in search of solutions to face the challenges of Industry 4.0. [29] presents a case study of an Estonian ICT company, Proekspert, where the authors define the necessary skills in the context of Industry 4.0 to explore how workers can be included in the future planning process. It is based on the creation of a prototype instrument to map the perceived skills gap. It will help to inform the design and development of a unified platform for defining and planning the skills around which a fruitful dialogue of all stakeholders can take

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place. In [8], a job that meets one of the challenges of Industry 4.0 which is the qualification of future employees with the skills necessary to act and work in the transformed work environment. To meet this challenge and to have a successful implementation of new Industry 4.0 systems in organizations, the authors combine three approaches: sociotechnical system theory; competence-based view; competence models of the Evolute approach, with a revision and update of the latter.

Often technical skills help people to succeed in an interview, but they need general skills to keep a job and achieve professional development. The authors of [26], describe a methodology, centered on a mapping of the skills and personal qualities necessary to assess the specificity required by the industrial environment 4.0, after the application of a complex psychological evaluation system Abcd-M based on a psycho-lexical approach system compatible with the Big Five personality traits (OCEAN model) on successive series of students from Politechnica University in Bucharest. A map of the capacities necessary for the assessment and selection of human resources able to work in the environment of Industry 4.0 was conceived. Continuing on this path, and towards developing ethical leaders, in a survey [31], young workers indicate that the top four skills employers need to ensure long-term success are interpersonal skills, confidence/motivation, ethics/integrity and critical thinking. In [30], qualitative information is provided from an ongoing collaborative research project involving a variety of manufacturing stakeholders in Northern Italy, to meet the challenges of changing technical skills in the context of Industry 4.0. The results help to shed light on manufacturing skills needs related to Industry 4.0, to prepare the ground for future research on the subject.

The authors of [10] have chosen to help SMEs to cope with the Industry 4.0 trend and prosper in the future, to provide it with technological support that can help them plan, direct and monitor the transition process, as well as develop their employees. This fact belongs to the objective of the Adaption project. In this article, the authors describe the work in progress, in particular on the tool using the newly created models of progress and maturity, but also on the associated skills development approach. A huge effort is now required in manufacturing companies in order to constantly update the skills of workers. In this context, the question of the evaluation of the training provided to workers is increasingly critical, since increasingly complex data must be collected in real time and correctly analyzed in order to define the skill level of workers and to introduce in case the necessary corrective actions.

[27] aims to present a training data evaluation tool based on the integration of a training evaluation ontology with a training analysis model to define the skill levels of workers. [3] presents an initial competence model and describe the dimensions of knowledge and skills necessary to Industry 4.0. This model can be used to create individuals for the training proposal or to assess the knowledge gaps existing in a company. The skills identified are classified as technical, behavioral and contextual. To define the educational needs, the authors propose to use six different dimensions namely technology, industrial sector, software life cycles, transversal skills, skills and job profiles. By combining factors of these dimensions, it should be able to provide a skill set at the individual or enterprise level.

III Investigation to Unveil the Required Skills by Industry 4.0

Predictions of future skill requirements in the manufacturing sector vary widely, depending on occupational requirements across sectors, regional variations and the degree of digitization [33]. Based on these requirements, surveys are carried out to find out the skills necessary for Industry 4.0. [30] is a research based on a qualitative methodology, aimed to achieve a double objective. On one hand, it identifies the latest manufacturing needs in terms of Industry 4.0 skills. On the other hand, it is an attempt to anticipate the needs of businesses in the near future. The results of this research also help to provide business, government and education with new perspectives relevant to the identification of the needs for recycling, improvement and development of future industrial human capital. Despite the limits of this study, it advances research and practice by providing a precise set of technical skills related to Industry 4.0.

Another survey was carried out on a group of companies selected randomly [32]. In order to diagnose the willingness of Polish companies to implement the concept of Industry 4.0, a questionnaire-based study focusing on individual employee skills, the authors adopted their approach that employee skills are one of the main challenges for the development of Industry 4.0. Based on the results of the German research conducted on the key skills of employees for the development of the concept of Industry 4.0, the most important skills, respondents indicated problem solving (69.84%) and personal responsibility for decision making (65.08%). The authors draw as a result that the essential general skills of employees in a modern enterprise will be mainly focused on understanding the problems and concepts of other disciplines and on openness to change and novelty, they argued that communication skills that are also cross-cultural, often with the use of virtual tools, will be more important. The authority of Engineer 4.0 will still rest mainly on solid technical knowledge, but the importance of general skills will continue to grow. The lack of importance of these skills is interpreted by researchers as a lack of willingness on the part of Polish employees to develop a new era.

[6] describes the results of a research carried out by its authors at the Polytechnic University of Peter the Great Saint Petersburg with the main aim of determining the status of use of digital technologies and advanced means of communication by students during their studies and their

preparation to work for the future digital industry. According to the research results, 30 to 35% of trainees do not actively use the latest means and communication skills of information technology. To address this challenge, it was proposed a number of measures reasonable to implement, additional training of university professors in the field of IT, as well as the development of more mobile applications, practical to use by students during their studies.

[9] makes a contribution to two important challenges currently affecting the industry and the companies: the definition of skills and the development of a skill model for Industry 4.0, the study focuses on three areas: Information System, Computer Science and Engineering which require academic training and will play a crucial role in the Industry 4.0, where the authors propose a skills model for the professions and develop a curriculum with content that can be applied in these areas of education. A skills-based program was developed, following a structured didactic approach, for this purpose, the SHL skill framework was used, therefore, 69 assessed skills were extracted. [17] considers that the main asset of the Industry 4.0 framework is the staff. The authors would like to determine what skills and expertise are necessary for young engineers to be ready for the framework of Industry 4.0. A questionnaire was developed at the level of three Italian universities, Brescia, Udine and Cassino, to analyze this situation. The questions aimed to investigate certain key problems of Industry 4.0, as well as the digital beliefs and behaviors of students when they entered the system university education. Answering a fundamental question: "Are our engineering students and educators effectively ready for the Industry 4.0 framework?". The results of the survey suggest the need to create a broader and better structured knowledge of the basic concepts linked to this new industrial revolution. Then, this knowledge should be improved and integrated, taking into account the revision of the educational content of the courses, in particular with regard to technical subjects.

For the same reason, in [25], data were collected from 85 manufacturing companies in the cross-border cooperative region of Lubuskie / Poland and Brandenburg / Germany. Respondents were managers and general managers. They were asked to rate the characteristics of employees in terms of the most important for Industry 4.0. They stated that they had sufficient knowledge of the assumptions of the idea for Industry 4.0. In this article, the authors are confronted to challenges from industry 4.1 which are the evaluation of the qualitative factors in the basic skills for Industry 4.0 in manufacturing companies, and the selection of employees with the appropriate skills to undertake business projects. The proposed approach, presenting the weighting of basic skills, makes it possible to assess a potential employee in manufacturing companies.

IV. NEW TECHNOLOGIES FACING THE CHALLENGES OF INDUSTRY 4.0

With the advent of Industry 4.0 and its components: Cyber-physical systems, Internet of Things, big data and cloud computing, robotics, systems based on artificial intelligence and additive manufacturing [26], companies will not only have difficulties in implementing new technologies, but some other challenges related to the adaptation of these technologies to have a highly qualified workforce. As Industry 4.0 takes shape, human operators experience greater complexity in their daily tasks: they must be very flexible and demonstrate adaptability in a very dynamic work environment. [12] emphasized the need for tools and approaches that could be easily integrated into daily practice and capable of combining complex methodologies with high usage requirements. For this reason, the authors offer a multi-layered modular solution, Sophos-MS, based on augmented reality content and an intelligent personal digital assistant with voice interaction capabilities. After deploying the approach and studying its potential through field experiments, the results of the experimental campaign were first checked to ensure their statistical relevance, then evaluated analytically to show that the proposed solution has a real impact on operators' learning curves and can make the difference between who uses it and who does not.

In [19], the authors present the aspects and limits of Virtual Reality (VR) technology to help VR developers create VR industrial environments that produce reliable / achievable simulations of the behavior of machines and real processes and stable operation of real processes afar. Industry 4.0 relies on virtual reality in order to reduce design and production costs, maintain product quality and overcome several technical compromises such as reducing the complexity of rendering while keeping rates high refresh rates or increasing resolution while providing a stable VR experience. [28] provides a first shared vision on how Augmented Reality (AR) can tackle four different challenges related to handling complexity in a Cyber-Physical Systems (CPS) environment: develop intelligent assistance systems for learning and performance assessment at the workplace, adapt job profiles accordingly, and address also the issue of work-life balance. The provision of such a technology will help to improve employability in a sustainable way by providing access to better paid jobs. It will also have a positive effect on well-being, enabling more people to keep their jobs through up-skilling, while job performance requirements increase.

V. THE COURSE TOWARDS ADAPTING HUMAN SKILLS TO INDUSTRY 4.0

The 4th revolution aims to push the industry to mutate towards connected factories where humans and machines collaborate throughout the production process. The digitization of the industry requires the rehabilitation of the infrastructure and the invention of new methods and

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processes. For these reasons, the industry makes call university teaching and researches to help them to adapt and qualify their workers according to the needs of Industry 4.0.

The rise of new digital industrial technologies and the diffusion of the Industry 4.0 framework have also led academia to be interested in possible changes that could involve the academic education of young people in general and, the learning of technical and engineering topics in particular [17]. An important part of the tasks of preparation for Industry 4.0 is the adaptation of higher education to the requirements of this vision, in particular the training of engineer, for which, [13] introduce a roadmap made up of three pillars describing the changes / improvements to be made in the areas of curriculum development, laboratory concept and student club activities. In order to bring about changes in behavior, attitudes and knowledge, a circular four-step experiential learning cycle model developed by Kolb is used. This model is selected as the most appropriate learning theory to adapt engineering education to the vision of Industry 4.0. Preliminary results from this implementation of this framework at the Turkish German University showed that it was possible to apply such framework and the underlying theory adopted from Kolb to adapt engineering education to the vision of Industry 4.0. [23] presents a concept on the development of an information system in order to formalize the reflections of the experts via business scenarios by input-output model and to verify the influence of sectors with high labor intensity-work on related professions and skills. The dynamic collection of input-output and labor market data via the internet is new to the system, where it provides an opportunity to test future scenarios on the effects of technological change on the labor market and determines the sets of skills for analysis. It helps to rethink the skill sets provided by training programs in the light of business scenarios derived from the business climate of Industry 4.0. The educational process has experienced difficulties in reaching national standards of competence in specific teaching tools and the best way to solve this problem is to compare different approaches, to study all the factors and to find the best practical tool in education, like in [21] where a questionnaire-based survey was conducted at the level of the Korean University of Technology and Education with the aim of carrying out a comparative study of two university courses of engineering to present the difference between the effect of education based on virtual reality (VR) and traditional education on learning robotics. An expert method, interviews with focus groups and a comparative study are used by the authors to achieve this objective. The authors studied the impact of different teaching methods on the development of students' skills. They also analyzed the effect of VR training in the classroom and found that there is a significant impact of the report CQI (Channel Quality Indication) on the performance of the teacher's teaching system. [22] is a part of the Erasmus + project "Approach to training in the workplace in the field of Industry 4.0 for a competitive European industry" - iNduce 4.0, it presents a state-of-the-art analysis of the knowledge and skill gaps on Industry 4.0 and the workplace learning requirements (WBL), using a large-scale survey of 6 European countries. The researchers defined the key points concerning the development of the iNduce 4.0 training course and the iNduce 4.0 practical methodology for the WBL. It provides awareness of the subject Industry 4.0, the training modules developed, the necessary skills and the proportion of theory and practice. [15] focuses on the facilitation of mobile learning processes in technical vocational education and engineering as well as its integration in learning about employment scenarios in Industry 4.0. The need of mLearning (mobile learning) applications that support learning in the real work process was motivated by two areas of application: laboratory courses, Industry 4.0 where in the latter, learning processes can be triggered by data cyber-physical systems of work processes. This allows mobile training on work scenarios. The author proposed the use of competence extracts instead of complete documents easily accessible via QRCodes, NFC or process data.

VI. Skills Approach

All these challenges require continuous innovation and learning, which is dependent on people and enterprise's capabilities. Appropriate management approaches can play a vital role in the development of dynamic capabilities, and effective learning and innovation climate. [2] stresses the important role of a learning factory (LeanLab) to improve university education, company training and practical research in the fields of industrial engineering and logistics. The authors present the current state of LeanLab and illustrate the next concrete steps towards an Industry 4.0 learning factory. [11] describes the design of a learning factory for Industry 4.0 that meets the growing demand for future skills of production personnel. But it focuses on soft skills such as decision making, group work and performance monitoring. [7] presented a learning model based on serious games, thought for industrial production plants, as a viable alternative for the development of professional skills. [14] presents a structured integrated vision of computer-aided applications (CAx) and Product Lifecycle Management (PLM) tools and their learning, for this purpose the author to propose Learning by project (PDB) as an approach to provide a learning experience that facilitates the development of skills and competences of Industry 4.0. It uses the Fusion 360 applications from Autodesk and DExperience from Dassault Systems, which have functionalities adapted to the implementation of collaborative learning based on a project. To enable future executives and workers of a factory to meet the challenges of an increasingly digitalized production system, other skills must also be addressed according to future production scenarios in the sense of Industry 4.0. [16] makes the abstract vision of Industry 4.0 more tangible using a Learning Factory approach in combination with scenario-based learning. The TU Wien Industry 4.0 pilot plant served as the basic infrastructure for the implementation of this concept. In order to supervise all the skills required, the authors have developed a preliminary skills catalog in which they have distinguished skills according to the skills framework of Rosenstiel and Erpenbeck and according to the typical roles in production. They are based on the RAMI4.0 architecture model, to create a "problem skills cube" serving as a reference for the targeted development of problem-specific skills and educational formats. This theoretical approach is intended to be a first step towards a more tangible vision of Industry 4.0 in collaboration with the pilot plant of Industry 4.0.

[18] presents a generative method led by a model used to adapt and reuse a set of learning components for the delivery of a skills development program concerned with a given learning objective and which serves a specific educational context, t describes a generative (IE) Instructional Engineering method used to create and adapt Competence Development Programs (CDPs). Such adaptations can be made at the time of conception or at the time of learning, which complicates the task of educational design. The generative framework of the work consists of a functionality model, a set of learning components and a transformational approach based on the meta-model to eventually generate the learning artifact. Another learning space presented in [20], the makerspace, a type of Science, Technology, Engineering, and Mathematics (STEM) creation space, where students must combine skills and knowledge in the fields of science, technology, engineering and mathematics to create, build and review a product, the Maker space in is different from project-based learning because these products do not necessarily have to take the form of projects such as tools, prototypes or designs. The model developed was called Heat STEM Makerspace and from analysis and discussion, the authors concluded that the Heat STEM creation space could be used to stimulate creative thinking, critical thinking and problem solving. The design model could guide the teacher to help students explore their best STEM potential. Students also learn better because the model develops not only their 21st century skills, but also their STEM literacy in physics so that the model can promote higher order thinking skills. In industries, workers may use different types of machinery or have to perform manual tasks that require a specific sequence of actions. In both cases, they may be faced with unexpected events, which require great expertise, for these reasons.

[24] presents a concept of gamification suitable for application in Industry 4.0 environments in the context of knowledge sharing, thanks to this platform, workers can raise discussions on certain problems, such as solutions to execution failures of automation systems, publish multimedia content related to training on certain procedures or cases of solution errors and also answer questions from other colleagues. Other learning and knowledge-sharing environments are cited in [29]: IntelLEO, an ICT research project was initiated with the aim of developing intelligent technologies that support Learning and Knowledge-Building (LKB) activities in Intelligent Learning Extended Organization (IntelLEO). An example of real lifelong learning that prepares for a career and not a job, eDidaktikum environment initially intended only for teacher training in order to facilitate the exchange and collection of didactic information within universities and between them. To achieve this, the main aspects are the systematization of information, cooperation and social learning, as well as personal development and evaluation.

VII. CONCLUSION

The industrial revolution represents an issue of competitiveness for all industrial companies. Their objective is to overturn paradigms and make industry more communicative and more interactive in order to simplify all operations. Whether in terms of training, maintenance or production, using new technologies must be thought out in conjunction with other aspects of competitiveness, and in particular the rise in skills of human capital to all levels of the company. In this article, we have presented some research work which presented the human skills necessary to face Industry 4.0. This aspect is often displayed as a central concern by public policies, but few are the concrete devices to have emerged. Admittedly, many uncertainties about the development of the industry make it difficult to accurately anticipate skill needs. Howeevr, effective support for employees affected by the changes will be the key to the successful transition to the industry of the future.

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