Competences 4.0

Subjects: Others

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Most models classify competences 4.0 into 3 main categories: digital, social/emotional, and cognitive. However, analysis shows competences 4.0 are studied from isolated perspectives by different disciplines. There is no unified, comprehensive model. The researchers propose a more detailed model with 5 categories: psychosocial, metacognitive, linguistic, technical, and digital competences. Psychosocial competences include teamwork, leadership, flexibility, communication skills. Metacognitive competences involve learning ability, problem-solving, creativity, self-reflection. Linguistic competences relate to communication, foreign languages, interpretation, social skills. Technical competences cover specialized knowledge, data analysis, technology use. Digital competences involve information literacy, media skills, programming, cybersecurity. The model aims to be interdisciplinary and capture the complexity of competences needed for Industry 4.0.

Keywords: Industry 4.0 ; competences 4.0 ; social competence

1. Introduction

Industry 4.0 has been a leading force framing the societal, economic, and technological environment since 2010. Several other commonly known terms may point to the same phenomenon, such as the Industrial Internet, the Internet of Things (also the Internet of Everything), or the Big Shift [1]. With the application of modern technologies and transformation of processes, significant changes are expected as related work continues. At the same time, future production systems would also require new employee competences [2]. A multistage analysis often precedes decisions made by enterprises to implement Industry 4.0 (I 4.0) solutions or technologies. Determinants that influence the willingness to implement I 4.0 have been presented by Michna and Kmieciak [3]. The research results on small- and medium-sized Polish companies prove that open-mindedness, culture, and knowledge of organizational financial performance animations positively impact the willingness to implement I 4.0 solutions. Others, such as Horváth and Szabó [2], divide factors into specific categories: (a) areas of human resources such as increasing labor shortages, reducing human work, and allocating workforce to other areas; (b) financial resources and profitability mainly in the case of cost reduction; (c) managerial factors such as market competition and trends, increasing pressure and customer requirements, and new business model innovation together with demands for greater control and the need for continuous monitoring of company performance; (d) productivity and technological and process integration and cooperation. Based on the work of Stentoft et al. [4], enterprises decide to implement I 4.0 due to the following: legislation and standards changes; the organization’s strategy requires cost reduction; customer requirement changes; time-to-market improvements; the fact that competitors practice I 4.0; but also due to a lack of qualified employees. During the implementation of Industry 4.0, the willingness or drivers of the mentioned “Big Shift” must be investigated. This should be balanced by barriers that block or inhibit organizations from making new steps in the fourth industrial revolution era. In the literature, Moeuf et al. [5] and Müller [6] have identified several human factors that can affect the successful implementation of a project. These factors include employee acceptance, lack of competences and know-how, lack of cooperation among departments, lack of top management support, and unclear employee benefits. Human competences are viewed as both a driving force of change and a potential barrier, as noted by Michna and Kruszewska [7].

However, it must be mentioned at this stage that, in general, scientific discussions on competences 4.0 are rare compared to discussions on Industry 4.0 itself. Consequently, this research aims to map the discussions on competences 4.0 from quantitative and qualitative points of view. The former is based on a review of the citation database (the Scopus database was chosen because of its more comprehensive coverage of journals and publications), and the latter concentrates on a literature review. This should lead to answering the most relevant question, i.e., if there is currently a unique and comprehensive model of competences 4.0. It has been slightly over ten years since the introduction of the term Industry 4.0, and an analysis of Scopus-indexed publications shows that competences 4.0 stemming from this term is still not a

thoroughly examined phenomenon with a prominent research gap that needs to be filled. From a quantitative point of view, it can even be claimed that these discussions are scarce (**Table 1**).

Table 1. Distribution of the discussions on competences 4.0 (regardless of spelling) by publication type.

Query I	Article	Book Chapter	Conference Paper	Review	Total
"Competences 4.0"	**4**	**0**	**4**	**0**	**8**
"Competences 4.0"	**9**	**0**	**1**	**0**	**10**
"4.0 Competences"	**7**	**1**	**12**	**0**	**20**
"4.0 Competences"	**14**	**1**	**6**	**1**	**22**

As can be seen from the table, not only are the numbers symbolic, but differences in spelling can also be observed, suggesting that there is no single adopted approach to the discussion. Further analysis of how the discussions on competences 4.0 are distributed among scientific disciplines sheds light and explains that the phenomenon still needs to be represented in scientific discussions.

It is interesting to note that discussions on competences 4.0, regardless of the spelling, are substantially more common within the technical sector than within business and management (**Table 2**). However, this is partially compensated for by the appearance of discussions on competences 4.0 within social sciences and psychology that contribute to scientific discussions within business and management fields. Inequalities in discussions on competences 4.0 can also be seen in the geographical distribution of these discussions.

Table 2. Distribution of the discussions on competences 4.0 (regardless of spelling) by scientific field.

Query II	Computer Science	Social Sciences	Engineering	Business, Management, and Accounting	Decision Sciences	Medicine	Economics, Econometrics and Finance	Psychology	Environmental Science	Mathematics
"Competences 4.0"	**4**	**0**	**0**	**2**	**0**	**0**	**2**	**2**	**0**	**0**
"Competences 4.0"	**0**	**3**	**0**	**3**	**2**	**3**	**0**	**0**	**2**	**0**
"4.0 Competences"	**12**	**6**	**10**	**3**	**2**	**0**	**0**	**0**	**0**	**0**
"4.0 Competences"	**9**	**12**	**11**	**5**	**0**	**0**	**0**	**0**	**0**	**2**
Total	**25**	**21**	**21**	**13**	**4**	**3**	**2**	**2**	**2**	**2**

It is unsurprising that scientific discussions on competences 4.0 are most often carried out in Germany, where the term Industry 4.0 originates, and generally across Europe. However, these discussions have also extended to the US and Asia (as shown in **Table 3**).

Table 3. Geographic distribution of the discussions on competences 4.0 (regardless of spelling).

Query III	Germany	Poland	Spain	USA	Indonesia	Italy	Malaysia	Russian Fed.	South Africa	Ukraine	Unidentified
"Competences 4.0"	**0**	**5**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**
"Competences 4.0"	**0**	**1**	**0**	**3**	**4**	**1**	**1**	**0**	**0**	**0**	**0**
"4.0 Competences"	**8**	**0**	**2**	**2**	**0**	**2**	**0**	**3**	**0**	**0**	**0**
"4.0 Competences"	**3**	**1**	**3**	**0**	**0**	**0**	**2**	**0**	**3**	**0**	**0**
Total	**11**	**7**	**6**	**5**	**4**	**3**	**3**	**3**	**3**	**1**	**1**

2. Towards Competences 4.0

The reviewed publications describe the competences and qualifications of employees as the following: enabler [8], driving forces [8][9], opportunity [1], benefits [10], potentials [6], and chance [11], but also challenge [12][13], barriers [4], inhibitors [14], obstacle [15], roadblock, or concern for Industry 4.0 [2]. Different views and different perspectives enable one to investigate competences across multiple axes. The meanings of the statements above, based on definitions by Cambridge Dictionary, are presented in **Table 4**.

Table 4. Meanings of statements.

Statement	Impact	Description
enabler		a person or thing that makes something possible
opportunity		possibility of doing something
benefits	positive	something that helps or gives an advantage
potential		may become one in the future, although they are not one now
chance		the possibility that something will happen
barrier		something that prevents people from doing what they want to do
inhibit		to make it more difficult for someone to do something
obstacle	negative	something that is hindering progress or success
roadblock		something that is placed in your way to stop people to succeed
concern		something significant or impactful to an individual and affects them in some way
challenge		something that is difficult and tests individual ability or determination

Competences, as a factor positively impacting decisions regarding Industry 4.0 implementation, are mentioned in the literature as a driver, driving forces, enablers, opportunity, benefits, potential, or chance. The negative impact of competences or other human factors is stated in the literature as an inhibitor, obstacle, or barrier. It is often noted as a challenge difficult and tests determination on the way to Industry 4.0 implementation.

For example, "Industry 4.0 drivers are employees highly trained and skilled in robotics, nanotechnologies, microbiology or astronautics that communicate with robots and are supported by web technologies and intelligent support systems in their day-to-day activities" [9]. Social benefits from Industry 4.0 are as follows: fairer wage assessments enhanced human learning and augmented employee motivation [6]. The opportunities that Industry 4.0 gives humans, based on [12], are linked with reducing monotonous work. The same authors indicated the term challenge by the following: employee qualifications and adaptation, possibly fear, concerns, and lack of expertise. In consideration of significant challenges and obstacles, the following competences were selected: willingness to learn, creative problem-solving in social settings, ability to find practical solutions, understanding of network technologies, as well as data analysis and processing [12].

A lack of qualified workers has been pointed to as a driver and barrier at the same time by Stentoft et al. [4]. Additional barriers were a lack of readiness and requirements for continuing education of employees. Vuksanović Herceg et al. [1], based on works [12][16][17] mentioned the competencies of managers and employees and their resistance.

A new limiting factor in the development of Industry 4.0, based on [9], is population demography. Due to a negative natural increase in population and problems related to a lack of resources and lack of knowledge, the number of experienced and competent employees will increase. The author also mentioned a lack of knowledge as another barrier to Industry 4.0. He stated that a lack of culture, vision, or internal training in the digital domain, as well as a lack of specialists, are some of the obstacles to the accelerated development of Industry 4.0 [8].

From the point of view of concerns, the authors point to a lack of training and competences, as well as employee resistance; small- and medium-sized enterprises are concerned about a lack of resources and qualified personnel [6][12]. In the research by Mogos et al. [8], a significant barrier is the competency of personnel and a lack of a good understanding of implementing I 4.0. According to the research results of the indicated author, smoother digitalization could be enhanced by improving competences such as the use and understanding of sensor technologies, the use of Big Data, general IT knowledge, and the use of statistics [8].

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Competences (as factors with negative impact) represent one of the axes in the research regarding human resources in Industry 4.0. Another axis widely discussed in the literature is the typology of individual competency and their division into assigned groups. In studies on the subject, the following groups are pointed to:

According to Erol et al. [24], the future competences of all levels of employees were grouped into the following categories:

- Personal competences, which can be understood as the ability of a person to act reflectively and autonomously, the ability to learn/develop cognitive abilities;
- Social/interpersonal competences—the ability to communicate, cooperate, as well as establish social connections and structures with other individuals and groups;
- Action-related competences, refer to the ability of a person to take individual or socially constructed ideas to action;
- Domain-related competences refer to the ability to access and use domain knowledge for a job or a specific task.

Three other functional areas of human resource development mentioned by Hecklau et al. [18] are as follows: competences—defined as personal development, collaboration—defined as the development and structure of teams and the role of processes in organizational development. Based on the identified challenges, grouped according to PESTEL analysis, the mentioned authors divided competences by considering political, economic, social, technological, environmental, and legal factors.

The model of future employee competences proposed by Vrchota et al. [19] relies on two axes. The first axis contains groups of technical and personal competences, while the other axis consists of the classification into the following needs: “must have”, “should have”, and “can have”. Another model, indicated by Śledziewska and Włoch [20], considers the following:

- Cognitive competences such as creativity, logical reasoning, solving complex problems, critical thinking, and the ability to perform information quality assessment;
- Social competences such as cooperation, working in groups, people management, leadership, and emotional intelligence;
- Digital and technological competences, not limited to programming or data analysis but also considering knowledge about cybersecurity, all core Industry 4.0 technologies, the Internet of Things, augmented and virtual reality, artificial intelligence, etc.

3. Competences 4.0: Models and Approaches

What is the comprehensive model of competences 4.0, then? According to various researchers [21][22][23][24][25][26][27], this model is generally based on the three already mentioned pillars:

- Digital competences—connected with the use of technology of different levels of advancement, ability to solve problems with the use of digital tools, and knowledge about privacy and cybersecurity issues;
- Social and emotional competences—connected with interaction with others and coping with one’s own emotions, as well as the ability to cooperate in a group and demonstrate leadership and entrepreneurship;
- Cognitive competences—connected with ways of thinking, including processing and verifying information, creativity, critical thinking, and the ability to learn and reflect.

This approach is in line with the empirical research and findings of the McKinsey Global Institute [28], which shows that the need for the competences mentioned above in the context of the fourth industrial revolution is increasing concerning the labor market demands. However, this model is derived from an existing classical model of managerial competences, including technical, social, and cognitive competences [29]. However, there are more terminology overlaps here, for example, about future competences. The shift towards competences 4.0 is formulated by various researchers who claim that the competences of the future, such as digital, cognitive, and social ones, reflect the current requirements of future jobs within a broader concept of the fourth industrial revolution, or simply Industry 4.0 [18][20][30][31]. Others add that this shift also implies the need for interdisciplinarity, personal flexibility, and a project-based approach [17][32][33]. Consequently,

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the model of competences 4.0 must be enhanced with a managerial component, and it presents itself at this stage of the discussion as follows:

- Digital and technical competences—so-called hard competences. Digital competences are understood not merely as programming and data analysis but as a wide range of skills, from digital solutions to problems to expertise in online privacy and cybersecurity. They include, among others, specialist competences, such as processing of big data sets, use of computing clouds and the Industrial Internet of Things, integration, simulation and visualization of processes, and evaluation of technology and its products;

- Managerial competences, such as self and team management, creating your image, financial management, business strategies, project management, work psychology, organization and management, public relations, marketing and media, managerial economy, human resources, managerial, leadership, and entrepreneurship skills, quantitative methods and business statistics, ethics, risk management and changing management, and techniques in the context of social and technological change;

- Cognitive or thinking competences—including creativity, logical reasoning, and solving complex problems;

- Social and psychosocial competences—effective cooperation within a group, leadership, entrepreneurship, and emotional intelligence, including soft competences like personal flexibility and interdisciplinarity.

A similar approach is proposed by Fitsilis, Tsoutsa, and Gerogiannis [34] after Leinweber [35]. They postulate the following model of competences 4.0:

- Technical competences, such as state-of-the-art knowledge, process understanding, technical skills, etc.;

- Methodological competences, including creativity, entrepreneurial thinking, problem-solving, conflict-solving, decision-making, analytical skills, research skills, and efficiency orientation;

- Social competences, such as intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to be compromising and cooperative, and ability to transfer knowledge and leadership skills;

- Personal competences include flexibility, tolerance of ambiguity, motivation to learn, ability to work under pressure, sustainable mindset, and compliance.

Fitsilis, Tsoutsa, and Gerogiannis also add that “skills needed for Industry 4.0 are numerous and diverse”, some of them, for example, ICT skills, have not been standardized [34].

Other typologies of competences 4.0 can also be found in the literature. Differences in approach result mainly from specific contexts that researchers address. For example, Clavert [36] and Geryk [37] provide a list of skills—or constituting elements of competences, to be more precise—needed to overcome the challenges posed by Industry 4.0 from the point of view of the higher education system. The main objective is to equip students with the new qualifications needed in the future labor market. These skills include flexibility, adaptability, technological literacy, risk-taking, business thinking, and abilities connected with information management, cybersecurity, quality control, and sustainability. The above skills also directly refer to the broader digital, cognitive, social, and managerial dimensions of the competences 4.0 model.

Another example comes from industrial and manufacturing points of view. According to the bibliometric analysis carried out by Poszytek [38], the most prolific authors in the field, Stock and Seliger [39], enumerate the human factor as one of the essential elements in sustainable manufacturing. They stress the importance of ICT technical skills, social skills, creativity, and decentralized decision-making [40]. Here, a reference to digital, cognitive, social, and managerial aspects of competences 4.0 can be seen. As stated above, the literature review shows numerous instances in which researchers concentrate only on selected elements of these broad competence categories while discussing the concept of competences 4.0 [40].

Considering all the above discussions and bearing in mind that the social dimension of competences as such is stressed as most important in most of the models, it seems plausible to treat social competence as an overarching element of the whole competences 4.0 model, especially considering that depending on the model, its various constituting features can be found in all other pillars of that competences 4.0 model, namely technical, managerial, and cognitive ones. Similarly, cognitive competence, or, to be more precise, some of its elements, are interlinked, and economic environments and ecosystems determined by rapid technological advancement wherein a broad application of technologies and instruments of the digital economy are implemented are becoming a common reality. On a practical level, this new reality manifests

itself in advanced computing and connectivity thanks to the Internet, data analytics leading to increased business intelligence, and new ways of implementing human–digital interfaces such as virtual reality [30]. Again, apart from the technical dimension of this new reality, it is a psychosocial dimension with other pillars of competences 4.0.