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Industry 4.0 as a Challenge for the Skills and Competencies of the Labor Force: A Bibliometric Review and a Survey

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Abstract: The latest technological development called Industry 4.0, like the previous industrial revolutions, has also brought a new challenge for people as a labor force because new technologies require new skills and competencies. By 2030 the existing generation in the labor market will have a skill gap threatening human replacement by machines. Based on bibliometric analysis and systematic literature review the main aims of this study are, on the one hand, to reveal the most related articles concerning skills, competencies, and Industry 4.0, and on the other hand, to identify the newset of skills and competencies which are essential for the future labor force. Determining the model of new skills and competencies in connection with Industry 4.0 technologies is the main novelty of the study. A survey carried out among the workers of mostly multinational organisations in Hungary has also been used to explore the level of awareness about those skills and Industry 4.0 related technologies, and this can be considered the significance of the empirical research.

Keywords: Industry 4.0; skills; competencies; bibliometric analysis; survey; Hungary

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1. Introduction

The economic structure has changed over time because of technological development. This development started with the dawn of the first industrial revolution (1760–1840). After that, the world witnessed two more revolutions at the end of the 19th century and between the 1970s and 1990s [1,2]. The Fourth Industrial Revolution (4IR), which started at the turn of the millennium, is also called Industry 4.0 (I4.0), and it has been accelerated in the last decade. The term Industry 4.0 was originally mentioned as Industrie 4.0 at the Hannover Fair in 2011 and indicated a programme for the digitisation and strategic development of the German industry [3,4]. Since then, it has been widespread, although it has several definitions. For example, "Industry 4.0 is nothing more than a digital transformation" or "The next phase in the digitalisation of the processing industry". According to a different view, "Industry 4.0 is a vision sponsored by the German government for a more advanced processing industry". In a narrower sense and most often, as can be seen from the above definitions to some extent, it is related to industry and includes the new technologies that will result in a radical transformation of industrial production [5]. According to Reischauer [6], Industry 4.0 represents a major technological revolution, which takes place primarily in industry, factories, and production. This is why Industry 4.0 and thus the Fourth Industrial Revolution are often referred to as "smart factory", "intelligent industry" or "advanced manufacturing".

The use of Industry 4.0 emerging technologies to fulfill the requirements of production has caused a rapid change in the labor market which has been defined as a digital influence on the labor market. Industry 4.0 has affected many jobs, replacing humans with machines, as we can see e.g., during the check-in process at the airport and many other routine jobs.

Previous studies have confirmed that only highly skilled and qualified human resources will be able to control Industry 4.0 technologies [7–11].

Industry 4.0 emerging technologies require more than just performing a task or resolving a problem in each field, which is exactly the definition of the skill. Rather, the capability to meet complex demands, including interpersonal attributes to be self-driven for lifelong learning in each field as the competency definition states [12,13] and to be able to understand what the required skills and job profiles are, as well as having an understanding of the emerging technologies of Industry 4.0 is important. Therefore, Industry 4.0 has ten main technologies which are the driving forces of this revolution as follows:

1. Industrial Internet of Things (IIoT) is a communication technology which makes the connectivity between the things possible. "Things can be anything like an object or a person." [14].
2. Cloud Computing (CC) is an alternative technology which enable sharing the storage of each data using on the internet for the companies which are outsourcing IT services as well as individuals [15].
3. Big data is a huge amount of data generated in a homogenised way as objects on the network. This data can be structured, semi-structured and unstructured. The value of big data is that it is organised with accessibility [16].
4. Simulation is an essential element of Industry 4.0, as it is a powerful tool to draw and evaluate many scenarios, not only in the manufacturing systems. It is also a powerful tool in the field of knowledge sharing and training [17,18].
5. Augmented reality is a system able to process information by combining real and virtual objects in a real environment in an interactive way combining 3D in real-time [4,18,19].
6. Additive manufacturing can be described as a rapid prototyping, solid freeform manufacturing, layer manufacturing, digital manufacturing or 3D printing [20,21].
7. Horizontal and vertical systems integration: I4.0 systems integration has two approaches, [22] which are enabling real-time sharing [18].
8. Autonomous robots refer to Artificial Intelligence (AI) [3,23].
9. Cybersecurity (CS) may serve as a new term for a high level of information security, and through the word "cyber" it spreads to apply also to industrial environments and IoT [4,18].
10. Cyber-physical systems (CPS) can be viewed as an innovative technology that permits control by integrating physical and computational environments of interconnected systems [18,24].

In the operation of these, Industry 4.0 technology operators play an important role. The concept Operator 4.0 became popular among studies referring to the qualified persons for those technologies. Operator 4.0 is also known as a smart operator, and it defines this as "a smart and skilled operator who performs not only 'cooperative work' with robots, but also 'work aided' by machines and if needs employing of human cyber-physical systems, advanced human-machine interaction technologies, and adaptive automation towards human-automation symbiosis work systems" [11,25,26]. In order to achieve the concept of Operator 4.0, which represents the future of workplaces, a set of skills is needed to integrate the workforce into I4.0. This integration can be called human-cyber-physical systems (H-CPS). Those systems are created to enhance the human-machine relationship [27].

Operator 4.0 knowledge transfer methodologies are aimed to create an environment to reach the concept (CPS) to improve the abilities of the workforce by allocation of tasks to machines and operators overseeing the ructions to the machine, which can be programmed into a machine, as an aid to handle uncertain events [11,28]. That can sum up the abilities of the human and machine in optimised manufacturing. To infer the cognitive states and emotions associated with the decision-making and operator behavior, the Operator 4.0 concept requires precise chronological time-harmonisation of the operator actions, sensory data and psychophysiological signals [29]. Moreover, the study aims to upskill and train the existing labour to be able to use the Industry 4.0 technologies in an innovative way. In the future, the number and composition of employees will also transform [30,31].

The most visible consequences of the use of new technologies can most likely be expected in industrial employment. On the one hand, the increase in automation, digitalisation and robotisation will reduce the demand for living labour in industrial production; thus, a smaller number of people will work in the manufacturing industry. On the other hand, thanks to new technologies, the quality of the workforce is also changing. Among the few industrial employees, there will be fewer low-skilled, physically employed and more qualified, intellectually skilled employees. According to a survey conducted in 37 countries, as the use of industrial robots increases, the proportion of people doing routine work among the employees, who are usually less educated, decreases [32]. Some 80 million low-skilled workers in the EU could lose their jobs as a result of automation and robotisation, while in the US, it is estimated that 47% of jobs could disappear [33,34]. Not only are old jobs and occupations transformed or eliminated, but new ones (e.g., data scientists) appear. Some of the new jobs will have different requirements on the workforce than the current ones. That is why new or different knowledge, abilities and skills will be needed more than before, and this will also place a heavy burden on education at all levels. It is likely that there will be high demand in the labour market for those who have adequate competencies in software development and information technology, as well as in info-communications, because the use of software, connectivity and analysis will increase [35]. In addition, many other skills and capabilities (e.g., flexibility, creativity, problem solving, decision-making, etc.) are needed to meet the labour market challenges of the coming decades. This also shakes the world of work to its foundations and may lead to serious problems [36]. Consequently, it is very important to identify the new skills and competencies, which can be relevant in the future. That is the research gap that this study intends to fill by replying to the following study questions:

RQ1: What are the top-cited articles concerning Industry 4.0 jobs related to needed skills and competencies?

RQ2: What are the trends of required skills and competencies in Industry 4.0 jobs among the different sectors of the economy according to the top-cited articles in relation to the topic?

RQ3: What is the level of awareness about Industry 4.0 emerging technologies among the employees of mostly multinational companies in Hungary?

The replies to these questions contribute to set up a new model for Industry 4.0 skills and competencies, and this can be considered the main novelty of the study. The empirical research is significant because it makes an attempt from a practical viewpoint to reveal the level of current awareness of skills and competencies related to Industry 4.0 technologies.

The study has five major parts. After the "Introduction", the "Materials and Methods" are presented with particular regard to the major steps of the research process. Section 3 demonstrates the results of the bibliometric analysis, which describes the database of the study and the results of the survey concerning the level of skills and the awareness level concerning Industry 4.0 technologies and needed competencies. Section 4 is the discussion of the results, and, finally, the conclusions follow.

2. Materials and Methods

2.1. The Process of the Research

Reaching the study aim requires going through study goals. Thus, reaching the best profile fit for the human workforce to meet the requirement of Industry 4.0 needs to explore the most related scientific studies on the given topic. Therefore, a hybrid method of a bibliometric analysis on the Scopus database and systematic literature review (SLR) was applied on the most cited articles. After reaching the results of the conducted search, a survey was carried out mostly among employees of multinational organisations in Hungary to reveal the awareness level concerning Industry 4.0 technologies and the new required skills. The major phases of the research work were the following:

The first step was to formulate the study questions, which allowed us to screen the data sets and include and/or exclude the desired documents.

The second step was data collection. Study data were collected from the Scopus database using the following query in the advanced search: TITLE-ABS-KEY ((“human factor”) OR (“operator”) OR (“smart operator”) OR (“workforce”) OR (operator 4.0)) AND ((“Industry 4.0”) OR (“4th industrial revolution”) OR (“smart factories”) AND (“training”) OR (“education”)) AND ((“skill*”) OR (“Competenc*”)) AND (EXCLUDE(PUBYEAR,2022)) AND (LIMIT-TO(LANGUAGE, “English”) OR LIMIT-TO (LANGUAGE, “German”)) to create illustrative maps. Then, other searches were also conducted to reveal data more related to the topic to avoid excluding important research from the discussion and conclusion. Those search queries were made concerning the job advertisements of Industry 4.0-related technologies. Also, a search query took place in the normal search instead of the advanced to compare the results with the study search. The last search was made to ensure the information novelty. Only one study was found in a peer reviewed journal which adopted a similar concept and method in terms of Industry 4.0 skills and competencies as well as using a bibliometric review. That research, however, used a different software together with different inclusion and exclusion approaches.

The third step was to apply the above-mentioned search query in the Scopus database and download the data sets for further analysis.

As a fourth step, exclusion and inclusion criteria were defined. Exclusion criteria were: (1) not English and/or German; (2) not related to Industry 4.0 related skills and competencies; (3) articles related to chemistry, biology, hydrology, medical and psychology aspects; (4) no full text available. Inclusion criteria were the following:

1. Peer reviewed manuscript in an impact factor journal or conference proceeding.
2. Related keywords have occurred at least three times in the title, abstract and keywords.
3. The document has been cited at least three times.

It is also necessary to note that the information for the documents that meet the requirements were the year of publication, language, journal, title, author, affiliation, keywords, document type, abstract and counts of citation which were exported into (CSV) format for the Scopus data set (This data set is compatible with VOS-viewer software.).

The fifth step was reporting the results using descriptive analysis. The software VOS viewer and Excel was used for bibliometric analysis.

As a sixth step, a small survey was carried out in 2022 among expats working in national and multinational organisations in Hungary to reveal the level of awareness concerning Industry 4.0 requirements for the new labor market using Google forms and Microsoft excel. Testing the awareness level in practice is also a new kind of approach in this topic.

The time span of the search was 2015–2021. The search was conducted from the middle of January with continuous updates until the beginning of April 2022.

2.2. Justification for the Methodology Used

VOS viewer (version 1.6.18) was used to analyse the co-authorship, co-occurrence, citation, bibliographic coupling, co-citation and themes. The research questions have been set up to make a bibliometric investigation of the needed skills and competencies in the Industry 4.0 paradigm. Using these methods and software such as VOS viewer helps to explore the relationships through visualising and mapping that can help in reaching the answers to the study questions in a logical way [13,19]. VOS viewer and equivalent software can supply a clustering mapping that can be a powerful tool for reaching the most important studies by knowing the citation strength, which explains the document's importance. Why have the top cited articles been used for the analysis? Studies have proved that concrete answers are more likely to be found in the top cited articles [37,38]. The stronger the citation position is the more valuable information the document holds in regard to the chosen topic.

The study objective is to find the most related set of skills and competencies that must exist in the workforce of the existing generation to cope with Industry 4.0. For those reasons, many keywords concerning the topic have been reviewed to reach the most related keywords. The explanation for choosing them is that the concept of Industry 4.0 is known in a decent number of studies as the Fourth Industrial Revolution. The other variable of the study is the human factor, which is known in most of the studies as the Operator or Operator 4.0. Sustainability was chosen as a keyword combined with the rest of the keywords because the studies which are concerned with the replacement of humans by machines (human-centered studies) have the keywords of training and education. The last variable is the skills and competencies combined. The reason for choosing, for example (Competenc*) is to relate all the studies that have competence or competencies all at once. Those areas of research will help in revealing the most related skills and competencies that are needed for Operator 4.0 in the era of Industry 4.0 [39]. They will form the skills and competencies model of the study.

3. Results

3.1. Bibliometric Analysis Results

In this section, first, the results will refer to the first RQ1. Running the search on the Scopus database, 588 documents were found, covering the years of 2015–2021 in all the fields, except for those mentioned in the exclusion criteria. Then, their number was decreased to 266 using the condition of exclusion (three citations at least per document). Dates of the search were in January 2022.

After that, using VOS viewer software, the citation analysis of the documents was conducted to determine the top cited articles in the given topic and to create a map depicting how much they are connected by the citation links of the documents and authors. Then, the articles were examined to help to create an image of what are the most suitable skills that can be built through training to reach the efficiency of the competencies in the workplace to cooperate with Industry 4.0. The final result of the top 20 cited articles in concern of Industry 4.0 skills and competencies is given in Table 1.

Table 1. Top twenty cited documents in relation to skills and/or competencies, training, and Industry 4.0 emerging technologies.

Ref. Number	Document Title	Number of Citations	Links	Journal Name	Journal Impact Factor	Journal Cite Score
[14]	Scanning the Industry 4.0: A Literature Review on Technologies for Manufacturing Systems	378	0	Engineering Science and Technology, an International Journal	4.336	9
[9]	Holistic Approach for Human Resource Management in Industry 4.0	297	21	Procedia CIRP	0.6	3.3
[10]	Smart operators in industry 4.0: A human-centered approach to enhance operators' capabilities and competencies within the new smart factory context	249	29	Computers & Industrial Engineering	5.431	7.9

Table 1. *Cont.*

Ref. Number	Document Title	Number of Citations	Links	Journal Name	Journal Impact Factor	Journal Cite Score
[16]	Big data analytics as an operational excellence approach to enhance sustainable supply chain performance	126	1	Resources, Conservation and Recycling	10.204	14.7
[19]	Supporting Remote Maintenance in Industry 4.0 through Augmented Reality	119	5	Procedia Manufacturing	1.794	1.39
[24]	Placing the operator at the center of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems	107	5	Computers & Industrial Engineering	5.431	7.9
[11]	Enabling Technologies for Operator 4.0: A Survey	85	6	Applied Sciences	2.679	3
[30]	Industry 4.0 and the human factor—A systems framework and analysis methodology for successful development	71	4	International Journal of Production Economics	7.885	12.2
[40]	Influences of the Industry 4.0 Revolution on the Human Capital Development and Consumer Behavior: A Systematic Review	71	10	Sustainability	3.251	3.9
[31]	Empowering and engaging industrial workers with Operator 4.0 solutions	71	3	Computers & Industrial Engineering	5.431	7.9
[39]	A training system for Industry 4.0 operators in complex assemblies based on virtual reality and process mining	69	0	Robotics and Computer-Integrated Manufacturing	5.666	12.5
[37]	Text mining of industry 4.0 job advertisements	68	4	International Journal of Information Management	14.098	18.1
[41]	Ageing workforce management in manufacturing systems: state of the art and future research agenda	62	3	International Journal of Production Research	8.568	10.8
[42]	Rethinking Human-Machine Learning in Industry 4.0: How Does the Paradigm Shift Treat the Role of Human Learning?	57	4	8th CIRP Sponsored Conference on Learning Factories (CLF 2018)	N/A	N/A
[43]	Estimating Industry 4.0 impact on job profiles and skills using text mining	55	2	Computers in Industry	7.635	12

Table 1. *Cont.*

Ref. Number	Document Title	Number of Citations	Links	Journal Name	Journal Impact Factor	Journal Cite Score
[44]	Augmented reality-assisted robot programming system for industrial applications	54	0	Robotics and Computer-Integrated Manufacturing	5.666	12.5
[45]	A framework for operative and social sustainability functionalities in Human-Centric Cyber-Physical Production Systems	53	2	Computers & Industrial Engineering	5.431	7.9
[46]	Visual computing technologies to support the Operator 4.0	49	0	Computers & Industrial Engineering	5.431	7.9
[47]	Social Factory Architecture: Social Networking Services and Production Scenarios Through the Social Internet of Things, Services and People for the Social Operator 4.0	48	1	IFIP International Conference on Advances in Production Management Systems	N/A	N/A
[48]	Dynamic task classification and assignment for the management of human-robot collaborative teams in work cells	44	0	The International Journal of Advanced Manufacturing Technology	3.226	N/A

Source: based on Scopus database edited by authors.

According to the Scopus database, the most cited article had 378 citations, while the least cited one had only 44. However, the article published in the journal International Journal of Information Management with the highest impact factor had only 68 citations. At the same time, the second most cited article had the lowest IF. Thus, it seems that there is no close correlation between the number of citations and the value of impact factor. Figure 1 of the database shows the connectivity among the documents using the document citations as the unit of analysis because the software has excluded some documents and shows only the connected ones. Bigger dots or circles represent more cited documents (Figure 1).

The following results refer to RQ2: What are the required trends of the skills and competencies concerning Industry 4.0 that can fit different professions among the different economic sectors?

VOS viewer was used for mapping the data extracted from Scopus and the top twenty cited articles to help to create the most adaptable skills and competency attributes model. A competency model is a descriptive tool that identifies what are the required competencies to perform a job effectively [1,8,9,37,43,49–54]. Therefore, these four sets of competencies are the most used and accepted in the related studies of the study database (Table 2).

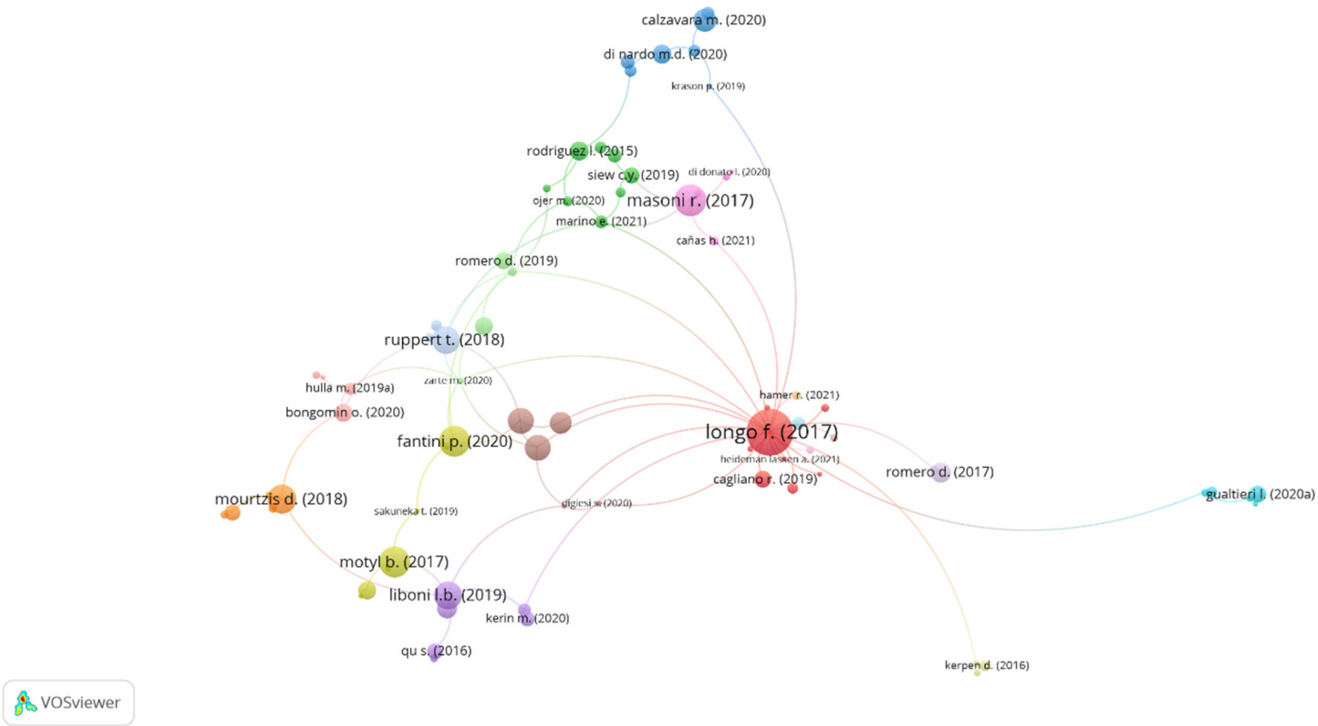

Figure 1. The most connected documents of the database by citations. Source: based on Scopus database edited by authors.

Table 2. A model for Industry 4.0 competences.

Competency Category	Competencies	Related Studies
Personal	(Flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset)	[1,8,52,54,55]
Social/Inter-personal	(Intercultural skills, language skills, communication skills, networking skills, teamwork, ability to transfer knowledge, leadership skills)	[1,8,51,54,55]
Technical	(Technical skills, media skills, coding skills).	[1,8,54–57]
Methodological	(Creativity, research skills, problem-solving, conflict solving, decision making).	[1,8,54–57]

Source: based on Scopus database edited by authors.

The competencies mentioned in Table 2 are required by many companies for the new jobs, which are related to Industry 4.0, for example, supply chain analyst, supply chain engineer, CPS and IoT for a robotised production engineer. More results on the new jobs which have been created by Industry 4.0 can be found in only four studies [37,58–60]. The bibliometric analysis has revealed the top twenty countries in this field of the research using citation as the basis of comparison. It is presumable that the majority of these countries are advanced in the application of Industry 4.0 technologies and/or in their research (Table 3).

Table 3. Top twenty contributed countries in the given field.

Country	Documents	Citations	Total Link Strength
Italy	78	1311	133
United States	77	604	46
Germany	49	399	53
India	37	224	12
United Kingdom	35	381	9
Spain	29	348	37
Malaysia	24	78	8
Australia	23	217	13
Austria	22	112	10
Sweden	22	277	36
Portugal	21	451	16
Poland	20	54	12
Russian Federation	19	64	2
South Africa	19	85	11
Brazil	17	182	43
Turkey	15	83	6
China	14	230	15
Canada	13	161	17
France	13	178	16

Source: based on Scopus database edited by authors.

Most of the publications were published in Italy, the US and Germany, and the number of citations was also the highest in these countries. The total link strength means the connection between one document and another by a different author/s in Industry 4.0 topic. The stronger it is, the more citations it has from more than three authors in more than three documents.

A special spatial pattern of countries can be created by the database using the citation links between the documents as the unit of the analysis as well as the authorship analysis concerning Industry 4.0 skills and competencies (Figure 2).

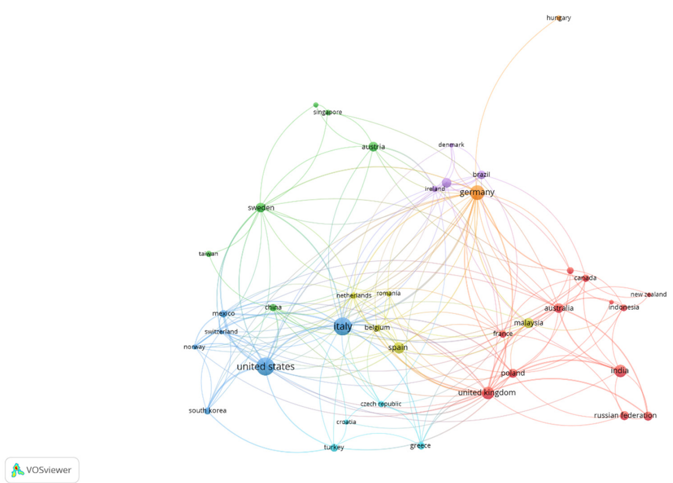

Figure 2. The most connected countries of the database by citations. Source: based on Scopus database edited by authors.

The most important keywords which were mentioned in each document at least 3 times and the connectivity among them also have a special pattern (Figures 3 and 4).

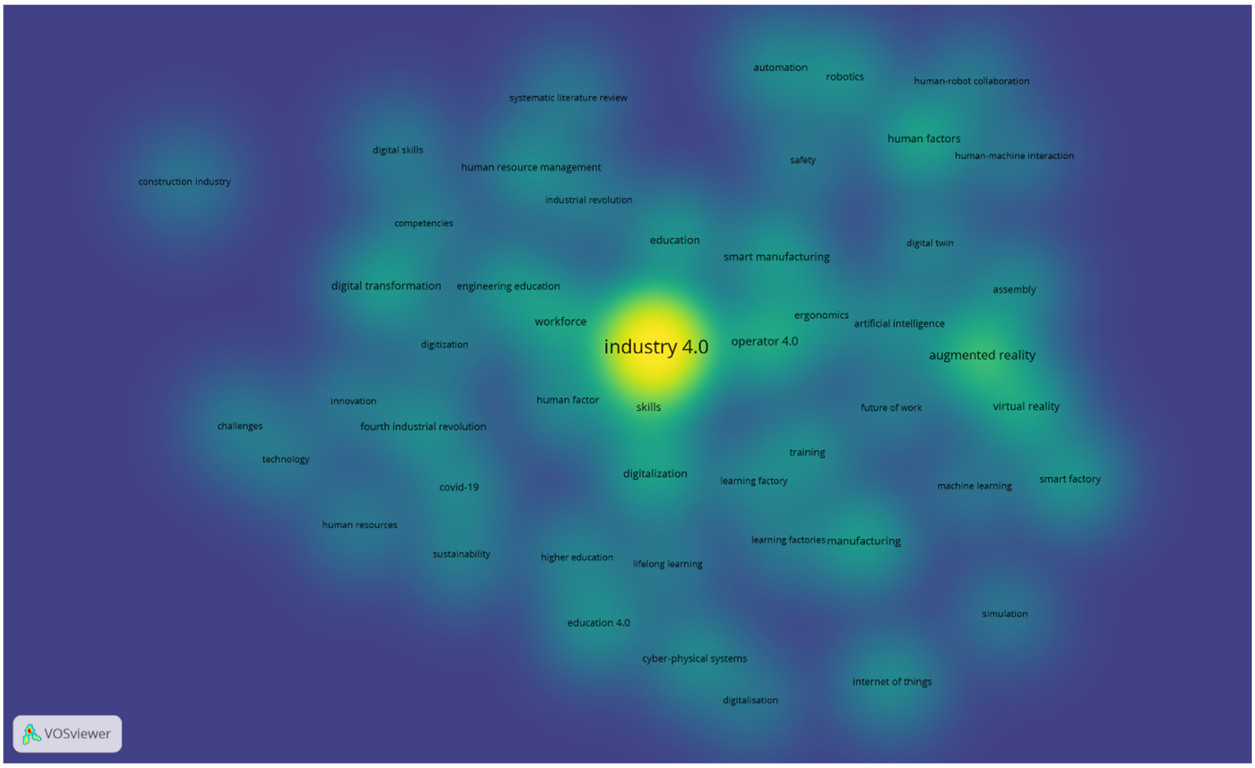

Figure 3. Database by keywords. Source: based on Scopus database edited by authors.

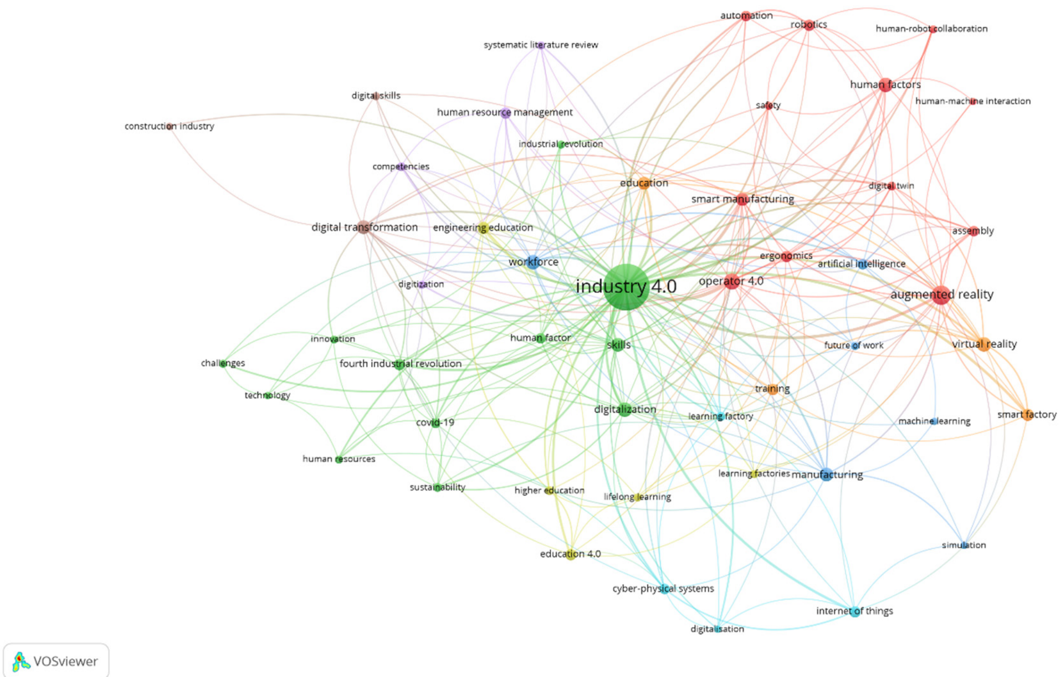

Figure 4. Database by keywords and the connectivity among them. Source: based on Scopus database edited by authors.

All keywords are connected to a big dot, which is Industry 4.0. This is probably because of the popularity of the word itself. Augmented reality is the other, most common keyword, which takes the second place in the intensity of connections and the third is the Operator 4.0, and the reason for this is that most of the studies were related to skills and competencies.

3.2. Industry 4.0 Awareness and Its Impacts on the Labor Force Based on a Survey

To answer RQ3 (What is the level of awareness about Industry 4.0 emerging technologies?), a survey was conducted in March 2022 among expatriates working primarily at multinational organisations in Hungary. The survey was shared using Google forms, which is a popular method as it makes it possible to create and share the questionnaire as the study requires.

The questionnaire consists of four major parts: respondents' personal data, Industry 4.0 concept, impacts of Industry 4.0 and skills and competencies. The survey had open and close questions and Likert scale questions to reveal the awareness level and the skills and competencies level among the sample. Also, the sample was asked about the relationship between technology and the COVID-19 crisis.

Only twenty expatriates took part in the survey. Their number or this sample is too small to generalise any of the results, but they are sufficient to indicate the level of awareness concerning I4.0. The participants of the study were selected because they were occupying positions related to I4.0 technologies in different sectors of the economy, and the reason that the employees of multinational companies were asked is that those companies attract talent from all countries. They are also known for their innovation, research and development, which makes them the best place for such technologies and have already started using these new technologies.

The major characteristics of the respondents are the followings:

- Gender: 25% female, 75% male.
- Age: 75%, 25–34 years old; 20%, 35–44 years old; 5%, 45 years and older.
- Education level: 50%, postgraduate; 35%, graduate; 15%, non-graduate
- The respondents worked in different positions in different fields of the economy. They were the following: marketing, computers, discrete elements methods, English literature, crisis management, senior submission and information specialist management, industrial control systems, transportation mechanics, mechanical engineer, architect, English studies, philologist, medicine, electrical engineering, structural engineering, communication, mathematics, environmental engineering (composting). These fields can give some ideas about their knowledge regarding Industry 4.0.
- Work experience: 50% of them had more than 3 years of experience in the given field.
- Twenty percent of the sample had not heard about the Fourth Industrial Revolution before.

Responses to the different questions are the following:

- To measure if COVID-19 crisis has accelerated the dependency on related Industry 4.0 technologies: 70% strongly agreed with the statement that "COVID-19 pandemic has increased the level of dependency on IT-related systems among the people".
- For the question "Whose responsibility is it to educate the people in order to meet the new requirements?" 40% replied and strongly agreed that it is the government's responsibility, while 45% agreed it is a lifelong learning and it is the people's own responsibility.
- When the sample was asked about robots replacing humans in the labour market and whether it is in the initial stages to say so, respondents estimated positively with the statement, "Robots are replacing humans in the routine jobs (for example: self-check-in at the airport, self-checkout at the supermarket), with 50% strongly agreeing, while 45% agreed on replacing humans in complicated jobs".
- The next question considered which set of the four skills is more important. Respondents estimated that Technical (technical skills, media skills, coding skills) and Methodological (creativity, research skills, problem solving, conflict solving, decision making) are the most important.

- As most of the new jobs related to Industry 4.0 require and/or prefer coding and programing skills, the study sample was asked about the ability of programing. Fifty percent responded that they cannot use programing languages, but the other 50% indicated the knowledge of more than one programing language.
- The responses for the question "How do you imagine your work 10 years later in terms of these technologies?" show that the majority of respondents imagined working from a home office and/or in hybrid form. However, someone wrote for the open-end question that:

"I work in a multinational company in technology business as a Service Desk Analyst, some parts of the system are already automated, I can imagine that my work will be less and less important". This reply also calls attention to the fact that in the future, not only will new skills and competences be required, but several jobs may also disappear. At the same time, new jobs, although in smaller numbers, will also emerge [34]. Some employees may also not be able to work because they cannot meet the requirements or because there will not be enough jobs as machines take over more work.

4. Discussion

This study has made an attempt to determine what kind of new skills and competencies will be required by Industry 4.0. Based on the bibliometric analysis and the questionnaire survey, it has become obvious from theoretical and practical viewpoints that the labour force has to be trained in order to be able to use the new technologies. For that reason, previous studies have focused on putting humans at the center of Industry 4.0 [9].

There is no doubt that having humans at its center is the key to the success of Industry 4.0. Thus, Operator 4.0 has a minimum requirement of the skills that those studies discussed [8,9,11,13,24,25,49,60–62], and they all agreed on a similar model described clearly in [9], which divided the skills into four main categories. They are the following:

- Personal (flexibility, ambiguity tolerance, motivation to learn, ability to work under pressure, sustainable mindset),
- Social/Interpersonal (intercultural skills, language skills, communication skills, networking skills, teamwork, ability to transfer knowledge, leadership skills),
- Technical (technical skills, media skills, coding skills),
- Methodological (creativity, research skills, problem-solving, conflict solving, decision making).

Different studies have discussed more than the four categories of skills considering scenario-based learning (SBL), Education 4.0 and vocational training [1,52,63]. In connection with these, the main question is: Which of them is believed to be the most suitable way of training the new workforce to meet the requirements of the labour market? Another study besides the ones which used the text mining techniques [37,43] compared most of the models resulting in "Five dimensions of worker readiness competencies model" [8] discussing most of the studies which have proposed other models of competencies to meet the requirements of Industry 4.0 [1,8,9,37,43,49–54], and all those studies agreed on the model used in this study. At the same time, other studies' models have focused on the skills needed to enhance the machine-human relationship [46]. The need for new behaviours in the machine-human relationship is important, and at the same time, the trust in the machine, the system and their connectivity can be challenging for the communication infrastructure in the era of cybersecurity.

Finally, we also have to mention that many studies highlighted how important it is to have the skill of decision-making as it appears in most of the studies as a soft skill, while other studies find it more related to AI systems. The question remains on what is the most important skill to have: programming or decision-making. As this study can conclude that both are indeed needed, decision-making can be more accurate and effective with the use of machine learning (ML) as one of the AI applications, as well as the use of the ML, which needs the ability to work with the cloud systems and big data that both require programming languages. This study has not mentioned anything related to programming so far; the needed programming languages for use in I4.0 applications, based on a study made on the LinkedIn database, were C, C++, assembly and JavaScript [37,64]. The results of the survey also highlighted the importance of using programming and coding skills in the age of Industry 4.0.

Parallel to the spread of Industry 4.0 technologies, a marked transformation will occur in all areas of life. New technologies first appeared in the manufacturing industry and continue to spread throughout the economy and society as a whole. The use of new machines and IT tools will require many new skills and competencies. This will most likely be a challenge for the workforce. Those who will have these new skills and competencies, which the study also revealed, will be in a more advantageous position in the labour market. There may be more to these in the future, as Industry 4.0 is constantly developing and making demands on the workforce. However, it is not only the workers and subordinates who have to constantly adapt to the new expectations through the development of their various skills and knowledge, but also the managers of the enterprises. In the age of the Fourth Industrial Revolution, a particularly large responsibility falls on managers, who are responsible not only for the training of the workers, but also for the development of their own expertise and skills. A great variety of knowledge, skills, abilities and competencies are necessary for them in order to be successful and for their business to function effectively. It is likely that, thanks to new technologies, certain skills (e.g., digital skills, communication skills, quick adaptation, system-level thinking, problem solving) will become more valuable, the absence or modest level of which may have unfavourable consequences for the development and future of the enterprise.

The empirical research also confirmed that the new skills and competencies will not be needed to the same extent in different sectors of the economy. Those interviewed considered technical and methodological skills to be the most important. The COVID-19 epidemic probably also contributed to the former, because the use of ICT increased, which required the development of technical skills. In the following years, in line with new technologies and the transformation of education, not only the number of the workforce, but also its quality (training, skills, competences, knowledge, etc.), will change. The labour market, the operation of enterprises and the management of human resources, as well as the economy as a whole, are being transformed.

The result of the study was narrow because of the inclusion criteria of the research, which resulted in excluding many of the most important documents on the topic of Industry 4.0. These articles were mostly in German and discussed the technologies rather than the skills and competencies. Examining [9] in relation to the most crucial citations for the definitions of Industry 4.0 as well as [14], which led this study to elaborate the definitions of Industry 4.0, another finding is that the citation score could be related to the name of the author and the connections between the authors rather than the in-depth information of the document. A further result is that most of the highly cited documents are not necessarily in high impact factor journals. It is probably because non-IF journals are used in a larger circle than the journals with impact factor.

The theory of the study that claims the COVID-19 crisis accelerated and increased the dependency on IT-related systems and Industry 4.0 emerging technologies is supported by the fact this crisis has opened our eyes to the ability of those technologies as crisis response and contingency plans as those studies have discussed before [65]. However, the remaining important issues and questions are related to the education of the coming generation: Is Education 4.0 in developed countries enough? Will the Operator 4.0 be able to control Industry 4.0 technologies according to the risk assessment of volatility, uncertainty, complexity and ambiguity? Answering the questions and applying Industry 4.0 necessitates the development of education and training. In the era of the Fourth Industrial Revolution, a significant transformation of the structure of education will be necessary at all levels (e.g., new subjects must be introduced, new methods must be used, the role of the teacher will change). This is a huge challenge for the current education system everywhere because it is necessary to provide trainings that provides marketable and competitive knowledge and professions, while it is impossible to know exactly what occupations there will be and what knowledge, skills and competencies will be required in the next years and decades.

5. Conclusions

Since the First Industrial Revolution, the labour force has had to adjust to the requirements of the labor market. In each industrial revolution, a new set of skills and competencies had to be developed. Since the Fourth Industrial Revolution has already begun, it is important to explore what the new expectations of the labour market are and what new human resource capabilities are necessary for the workforce to meet them. Based on bibliometric analysis and systematic literature review, this study determined the most related articles concerning skills, competencies, and Industry 4.0, and identified the new set of skills and competencies which are important for the future labour force. It has also evaluated several skill and competency models referring to the top-cited articles in the topic and more models referring to more recent articles published in 2020 that did not have enough time to reach a high citation score.

According to the models which have focused on interpersonal and technological skills, the most important skills and competencies are interpersonal skills, as many studies have confirmed that these are necessary in the workforce on all levels [23,31,38]. Interpersonal skills are important because they are the crucial area where human can surpass the machine. This study also focuses on the innovation competencies. These kinds of competencies can enhance the ability of the human to use the machine relationship to create and invent using the AI and ML at the maximum application, which will make a place for the human workforce in the workplace [62].

Fewer studies have focused on the technical and domain skills, which are more important in regard to the programming language, which is the way to communicate with the computer. It is presumable that in the upcoming ten years, these competencies will be categorized as communication skills and considered as a language, not a technical skill. Moreover, interpersonal skills and programming competencies will be necessary in all job profiles in the future, and the technical and domain skills to be developed based on the job profile. The question here is: What are the most important interpersonal skills? It can be found in the model of [52,66,67]. The experiences of the survey also confirmed that technical and methodological skills are the most important, the significance of which will probably continue to increase in parallel with the spread of Industry 4.0. For the latter, however, significant infrastructural, especially info-communication technology, developments are also necessary. In the future, what we cannot ignore is that the real application of this industry on all levels would need the glue of communication, which cannot be provided without the fifth generation of communication. Although humans will play the key role in the success of this transition, ensuring the material availability that helps in producing, for example, the chipsets of the computers theyalso have to face several other challenges (e.g., shortage of energy and water, climate change, different epidemics, economic crisis, digitalised world), the effects of which affect all fields of life and people's skills and competencies to varying degrees, encouraging them to continuously develop and adapt. In order for humans to cope with and adjust to them, it is extremely important to see clearly what kind of new skills and competencies will be important in the future, and this study has made an attempt at this.

The results of this research, on the one hand, draw attention to the new skills and competencies, which should be emphasized more at different levels of education. On the other hand, they can contribute to the development of human resources of enterprises and the elaboration of new training programs of educational institutions. Based on the lessons learned from the research, the study recommends that more attention be paid to the development of analytical skills in education and vocational training, which may be important in the adaptation of Industry 4.0, as well as to the teaching of subjects related to information and communication technologies.

There are several options for continuing the research. One of these could be to use another database (e.g., WOS) and make a comparison to confirm and refine the current results. Another possibility to continue the research is to widen the scope of the participants in the survey and to examine how much the various sectors and enterprises of the economy are prepared for the new challenges posed by Industry 4.0 technologies to the skills and competencies of the workforce. These studies can also contribute to defining the necessary structural changes in the economy, labour market and education in the age of the Fourth Industrial Revolution.

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