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The Landscape of Scientific Discussions on the Competencies 4.0 Concept in the Context of the 4th Industrial Revolution—A Bibliometric Review

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Abstract: The concept of Competencies 4.0 stems from a broader term of the 4th Industrial Revolution, also named Industry 4.0, which dates back to 2011, when the German Federal Government announced its high-tech strategy and policy towards increasing the competitiveness of the German economy during the Hannover Fair. These terms and concepts have been thoroughly and extensively discussed, analysed, and researched by experts within various scientific disciplines such as management, economy, psychology, education, human resources, informatics and systemics ever since. Due to the relevance of the Industry 4.0 concept in relation to current socio-economic challenges worldwide, the growing interest on the part of researchers and the proliferation of the above-mentioned terms in the literature, a network of patterns and relations has formed constituting a scientific landscape of the whole phenomenon. Accordingly, the aim of the analysis in this article is to map the landscape of scientific discussions on Competencies 4.0 in the context of the 4th Industrial Revolution. So far, some of the aspects of this landscape have been researched with the use of various databases, search engines and software in order to process and visualise retrieved data. All of these tools have their advantages but also their shortcomings. This research uses the Scopus database and the author's own algorithm to process the data. The results of the analysis provide a point of reference for scholars, practitioners, managers, policy and decision makers from various fields who search for sources which define Competencies corresponding to current and future socio-economic challenges in the context of the 4th Industrial Revolution.

Keywords: literature review; Competencies 4.0; Industry 4.0; Scopus; bibliometrics

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1. Introduction and Preliminary Literature Review

Since the landscape of scientific discussions on Competencies 4.0 and Industry 4.0 is constantly growing, there is a need to carry out up-to-date bibliometric reviews. The continuous build-up of sources in bibliometric databases can make some of the findings out-of-date relatively quickly. Consequently, the validity of such analyses has its time limits. Therefore, this analysis attempts to make its contribution to the continuum of a broader research in this field.

This literature review of the Competencies 4.0 concept in the context of the 4th Industrial Revolution aims at (1) depicting the scientific landscape of Competencies 4.0 and Industry 4.0 concepts; (2) familiarising interest groups with relevant and influential authors, as well as sources in the field. This should also further lead to:

- Better understanding of Industry 4.0 and Competencies 4.0 phenomenon and its consequences for education and training;
- Increased awareness and knowledge on how Industry 4.0 and especially Competencies 4.0 and the terms connected with them should be understood and interpreted;

- Establishing a long-term tool for observing the phenomenon in question;
- Further proliferation of Industry 4.0 and Competencies 4.0 concepts.

It must be also noted, at this stage, that the preliminary literature review serves here only to explain and define relevant terms on which the analysis in this article is based. In this respect, the analysis is carried out on the basis of the author's own choice of sources.

Industry 4.0, known also as the 4th Industrial Revolution, or I4.0 for short, is one of the elements of the High-Tech Strategy 2020 action plan announced in 2011 by the German Government whose aim was a more competitive, efficient, flexible, and digitalised production and economy [1,2]. However, the term "4th Industrial Revolution" was not brought to a wider public until 2016 by Klaus Martin Schwab, an executive chairman of the World Economic Forum [3]. Accordingly, this concept is relatively new, and actually what we deal with is only a decade of developments in this field. A presentation of the 4th Industrial Revolution in reference to all previous Industrial Revolutions can be found in Rojko [4] and Tay, Lee, Hamid and Ahmad [5]. What is distinctive and extremely useful for those who search for relevant and quality sources is that Rojko [4] also presents the concept of Industry 4.0 in the broader context of similar governmental initiatives worldwide. Additionally, a list of Industry 4.0 definitions is provided by Tay et al. [5] and Janik and Ryszko [6] as a result of a very thorough literature review and bibliometric analysis. However, the most comprehensive overview of the concept is provided by Górka, Thier and Łuszczyk [7] where the authors on the basis of their own elaborations depict all four Industrial Revolutions in reference to their main features, dates and duration, implementation of new technologies, as well as major economic and social consequences. Finally, placing the 4th Industrial Revolution in the broader context of the so-called three mega-trends, namely: demographic change, globalisation, and technological progress, is presented by Poszytek and Jeżowski [8]. While discussing the concept of the 4th Industrial Revolution, most of the authors enumerate the characteristic features that constitute its broader definition [3,5–7,9–11]. They are as follows:

- Internet of things: advanced connectivity of systems, services and physical objects enabling object-to-object communication and data sharing;
- Cloud computing: system logic that provides a huge space for data storage;
- Autonomous robots: robots which interact with each other and collaborate with humans;
- Big data: huge amount of data obtained daily from devices connected to the Internet;
- Simulation; modelling real or virtual processes by using real-time data to represent the real world in a simulation model;
- Internet of services: services provider on the Internet with services available on demand;
- Augmented reality: reality enhanced by virtual elements;
- Cyber-physical system and human-digital interfaces: systems that integrate humans with machines;
- Additive manufacturing/3D printing: implementation of new manufacturing skills for the purpose of integrating information technologies;
- Smart factory: intelligent factory that is based on Internet of things and cyber-physical systems (see above);
- Block chain: decentralised and dispersed data base.

As regards to the concept of Competencies 4.0, a traditionally structured state-of-the-art literature review was carried out by Priffti, Knigge, Kienegger and Kremar [1] who analysed how often Competencies 4.0 appeared in the specialist literature in the context of the 4th Industrial Revolution (Figure 1).

Figure 1. Number of papers mentioning competence. Source: [1] (p. 49).

It is worth noting that their analysis shows that various models of competencies for Industry 4.0 very often refer to the ability of communicating with people but not so often to leadership skills or creativity. Another review of references is provided by Dobrowolska and Knop [9] who present the most comprehensive model of Competencies 4.0. The summative version of it is as follows:

- Digital and technical: so-called hard competencies. Digital competencies are understood not only as programming and data analysis but as a wide range of skills —from digital solutions of problems to expertise in online privacy and cybersecurity. They include, among others, specialist competencies such as processing of big data sets, use of computing clouds and the industrial Internet of Things, integration, simulation and visualisation of processes, and evaluation of technology and its products.
- Managerial competencies: such as self and team management, creating own image, financial management, business strategies, project management, psychology of work, organisation and management, public relations, marketing and media, managerial economy, management of human resources, managerial, leadership and entrepreneurship skills training, quantitative methods and business statistics, ethics, risk management and changing management techniques in the context of social and technological change.
- Cognitive or thinking competencies: including creativity, logic reasoning, and solving complex problems.
- Social and psychosocial competencies: effective cooperation within a group, leadership, entrepreneurship, and emotional intelligence including such soft competencies as personal flexibility and interdisciplinarity.

It must be added that in some sources, Competencies 4.0 refers only to three main areas, namely: digital, cognitive and social [12–15]. However, it is mostly due to the fact that researchers, who propose such a model, include such skills as managing or coordinating people, entrepreneurship, and leadership in the category of social competencies and not managerial ones. Additionally, depending on the model, flexibility is included either in the cognitive or social category.

A similar approach, although with the use of slightly different terminology, is proposed by Fitsilis, Tsoutsa and Gerogiannis [16]. They postulate the following model after [17,18]:

(a) Technical Competencies such as state-of-the-art knowledge, process understanding, technical skills, etc.
(b) Methodological Competencies including creativity, entrepreneurial thinking, problem solving, conflict solving, decision making, analytical skills, research skills, and efficiency orientation.
(c) Social Competencies such as intercultural skills, language skills, communication skills, networking skills, ability to work in a team, ability to compromise and cooperate, ability to transfer knowledge and leadership skills.
(d) Personal Competencies that include flexibility, ambiguity tolerance, 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" and some of them, for example: ICT (information and communication technology) skills, have not been standardised yet [16].

Other typologies of Competencies 4.0 can also be found in the literature and differences result from specific contexts they address. In most cases, their aim is not to provide a universal framework for Competencies 4.0 but to concentrate on selected skills relevant for these contexts. For example, Geryk [19] and Clavert [20] provide us with a list of skills needed to overcome the challenges posed by Industry 4.0 from the point of view of the higher education system which is supposed to equip students with new qualifications needed in the new labour market. These skills are as follows: flexibility, adaptability, technological literacy, risk-taking, business thinking, and abilities connected with information management, cybersecurity, quality control and sustainability. In fact, the above skills also directly refer to the broader categories of digital, cognitive, social, and managerial spheres. Another example comes from the strictly industrial and manufacturing point of view. Stock and Seliger [21], one of the most prolific authors on Industry 4.0, enumerate the human factor as one of the most important elements in sustainable manufacturing. They place emphasis on ICT technical skills, social skills, creativity, and decentralised decision making. Again, the reference to digital, cognitive, social and managerial spheres can be seen here. Consequently, all these models feed into the search matrix of Competencies (see Query III below).

2. Analysis Design

In similar bibliometric analyses, various approaches have been used to collect and process the data from classical to automated ones. A comprehensive overview of these approaches can be found in Roblek, Thorpe, Bach, Jerman and Meško's paper [22]. For example, Priffti et al. [1], in their research on competency models for Industry 4.0, used a structured literature review with the use of digital libraries and Google Scholar as well as focus groups with academic staff. Accordingly, this approach can be classified as partly classical and partly semi-automated. Automated analyses were made by Janik and Ryszko [6] by retrieving the data from the Web of Science Core Collection in order to carry out mapping of the Industry 4.0 field and using VOSviewer software to visualise the data. Similarly, the bibliometric analysis of the impact of Industry 4.0 on sustainability is provided by Ejsmont, Gladysz and Kluczek [23] where, additionally, the Scopus database was used and, apart from keyword network analysis, citation network, and co-occurrence of keyword analyses were also performed. Fully automated and complex searching for multifaceted analysis can be supported by Leximancer software if analysis of a large body texts is needed. This software can look for terms that have a high probability of being linked within themes and concepts.

The aim of the analysis in this article is to map the scientific landscape of discussions on Competencies 4.0 in the context of the 4th Industrial Revolution. This analysis is based on the Scopus database. In the light of the aim of the analysis, only one database is used, which is supposed to contribute to clarity of the results. Additionally, a dedicated

algorithm, described below, was developed for data processing from publication titles, keywords and abstracts.

On the general level, analysis design is organised and structured along four main queries:

- Query I (QI): occurrence of Industry 4.0 OR industrie 4.0 OR I4.0 OR economy 4.0 OR 4th Industrial Revolution OR fourth Industrial Revolution in the publication title in various types of publications and their distribution across countries;
- Query II (QII): occurrence of competences 4.0 OR Competencies 4.0 OR skills 4.0 accompanying Industry 4.0 OR industrie 4.0 OR I4.0 OR economy 4.0 OR 4th Industrial Revolution OR fourth Industrial Revolution in the publication title and in the abstract;
- Query III (QIII): occurrence of Competencies 4.0 in the publication title, keywords and abstract across scientific fields or subject areas in reference to most common types of publications on the basis of the following search matrix:
  - ⇒ QIII.1: Digital Competencies OR digital competences OR technical Competencies OR technical competences;
  - ⇒ QIII.2: Managerial Competencies OR managerial competences OR team management OR team coordination or leadership OR entrepreneurship;
  - ⇒ QIII.3: Cognitive Competencies OR cognitive competences OR problem solving OR complex problem solving OR creativity OR critical thinking OR flexibility OR adaptability;
  - ⇒ QIII.4: Social Competencies OR social competences OR team work OR team collaboration OR team cooperation OR cooperation within a group OR leadership OR entrepreneurship OR flexibility OR interdisciplinarity.
- Query IV (QIV): co-occurrence of Competencies 4.0 in the publication title, keywords and abstract in the most common configurations, for example: QIV.1 AND QIV.2 OR QIV.1 AND QIV.3 OR QIV.1 AND QIV.4 OR QIV.1 AND QIV.2 AND QIV.3 and so on.

Not only does this approach facilitate mapping the scientific landscape of discussions on Competencies 4.0 but it also enables visualisation of how these discussions are positioned in the context of the broader deliberations on the 4th Industrial Revolution. Data from queries is also analysed in reference to sub-categories. However, before presenting further detailed steps and stages of the analysis, the explanation of the choice of the above query terms and wording is needed. Firstly, the terms: "competence", "competency" and "skill" are used here interchangeably. Although one can find various definitions of these terms in numerous sources, the preliminary literature review shows that in the context of the 4th Industrial Revolution, they all practically touch upon the same abilities and factors such as leadership, adaptability, flexibility, decision making, creativity, team work, and cooperation which also includes communication and networking. Similarly, QI includes terms that refer exactly to the same concept and are used as equivalents across literature depending on the context. For example, the French sources tend to use "industrie" whereas German ones prefer I4.0 [1]. Other relations between these terms are explained in the Introduction to this article.

On the more detailed level, the results of QI are presented in reference to the following aspects:

- Number of publications by their types;
- Country distribution of publications.

The results of QII are shown according to the following scheme:

- Number of publications and citations by year;
- Number of publications by country;
- Number of publications by type;
- Number of publications by subject area or scientific field.

The results of QIII and QIV are followed by the additional findings of:

- Occurrence frequency of keywords connected with the research subject matter;
- Most prolific authors and publications.

Accordingly, the scheme presented above aims not only at providing quantity indicators for measuring productivity in relation to number of publications and citations, but it also aims at measuring impact in relation to how research subject matter proliferates through countries, types of publications, and scientific fields as well as how the publications proliferate through citation.

As regards to the technical part of retrieving and processing the data in this research, the author used the following approach:

- QI and QII were carried out on the basis of Scopus in-built functionalities. Thanks to query logic of OR and AND, a set of publications was retrieved according to the methodological assumptions described above. The function OR and AND allowed to distinguish and analyse occurrence and co-occurrence frequency of defined and given terms. The function OR itself means the occurrence of at least one term in a given query whereas the function AND means the co-occurrence of two or more terms.
- Other operations connected with QI and QII were carried out in the form of data mining. In this case, the retrieval of information such as types of publications, countries of publications' origin, year of publications, etc.
- QIII and QIV were carried out with the use of the author's own script on the basis of data already retrieved from Scopus. The use of this script allowed searching for correlations which are not implemented in Scopus' tools.

3. Results and Discussion

Table 1 shows frequency occurrence of Industry 4.0 OR industrie 4.0 OR I4.0 OR economy 4.0 OR 4th Industrial Revolution OR fourth Industrial Revolution terms in the publication title across various types of publications.

Table 1. Number of publication types referring to the 4th Industrial Revolution concept.

Query I	Article	Book	Book Chapter	Conference Paper	Conference Review	Data Paper	Editorial	Erratum	Letter	Note	Review	Short Survey	Undefined
TITLE ("4th Industrial Revolution")	58	2	8	27	3	0	8	0	0	0	8	2	0
TITLE ("I4.0")	17	0	3	28	0	0	1	0	0	0	1	0	0
TITLE ("economy 4.0")	6	0	1	1	0	0	0	0	0	0	0	0	0
TITLE ("4th Industrial Revolution")	255	8	28	106	4	0	22	0	4	6	20	5	0
TITLE ("industrie 4.0")	334	2	5	144	0	0	35	0	0	33	9	26	0
TITLE ("Industry 4.0")	1883	7	232	2139	31	2	95	2	4	74	178	50	2
#1 OR #2 OR #3 OR #4 OR #5 OR #6	2345	19	276	2394	38	2	132	2	8	85	214	63	2

The data shows that the most common publication types referring to 4th Industrial Revolution concept are equally divided between conference papers and articles including the term Industry 4.0. This proves the already mentioned statement that the research subject matter is based on relatively new concepts and its various spheres are still being developed. The above data translated into publications distribution by country is as follows (Table 2).

Table 2. Countries with most publications.

Query I	Best	Second Best	Third Best
TITLE ("4th Industrial Revolution")	South Korea	South Africa	United Kingdom
TITLE ("I4.0")	Germany	Italy	Austria
TITLE ("economy 4.0")	Germany	Spain	Italy
TITLE ("4th Industrial Revolution")	South Africa	South Korea	United States
TITLE ("industrie 4.0")	Germany	Austria	United States
TITLE ("Industry 4.0")	Germany	Italy	United Kingdom
#1 OR #2 OR #3 OR #4 OR #5 OR #6	Germany	Italy	United Kingdom

For obvious reasons, the leading country in this ranking is Germany where, as stated in the Introduction, the concept of Industry 4.0 was coined. It can also be noticed that the term 4th Industrial Revolution is more common outside Europe. Detailed figures in relation to the usage frequency of the subsequent terms in the first three leading countries are presented in Table 3.

Table 3. Number of publications in three leading countries.

Query I	Germany	Italy	United Kingdom
TITLE ("4th Industrial Revolution")	11	5	13
TITLE ("I4.0")	20	8	1
TITLE ("economy 4.0")	3	1	0
TITLE ("fourth Industrial Revolution")	23	27	26
TITLE ("industrie 4.0")	469	4	7
TITLE ("Industry 4.0")	790	464	270
#1 OR #2 OR #3 OR #4 OR #5 OR #6	1049	504	314

Again, this table shows that the term Industry 4.0 substantially prevails in the three leading countries: Germany, Italy and UK, respectively. However, the term industrie 4.0 is also frequently used but only in Germany.

After outlining a contextual landscape, further analysis and presented data relate to both the Industry 4.0 concept and the concept of Competencies 4.0. Table 4 shows the number of citations and publications which include either the terms connected with Industry 4.0, or with Competencies 4.0 in the title and in the abstract of publications.

Table 4. Number of publications and citations by year.

Query II			
Year	**Number of Publications**	**Cumulative Number of Publications**	**Number of Citations**
2011	1	1	56
2012	3	4	14
2013	33	37	111
2014	104	141	5142
2015	260	401	7626
2016	626	1027	13,112
2017	1245	2272	20,022
2018	2211	4483	22,956
2019	3597	8080	17,182
2020	4172	12,252	8710
2021	1066	13,318	564

Both publication and citation figures show that the year 2016 marked a starting point for an accelerated proliferation of the Industry 4.0 and Competencies 4.0 concept discussions, which is coherent with the background information provided in the Introduction. It must be also noted that data for the year 2021 refers only to the first quarter, which is the time of writing this article.

The core of this discussion in reference to the issue of impact, defined as proliferation of relevant concepts through countries, across publication types and through subject areas or scientific fields, is presented in Table 5.

Table 5. Number of publications by countries, publication types and subject area, or scientific field.

Query II					
Country	**Number of Publications**	**Publication Type**	**Number of Publications**	**Subject Area/ Scientific Field**	**Number of Publications**
Germany	2337	Conference Paper	6195	Engineering	7753
Italy	1133	Article	5259	Computer Science	6386
United States	800	Book Chapter	643	Business, Management and Accounting	2345
China	741	Review	491	Decision Sciences	1888
United Kingdom	699	Conference Review	346	Social Sciences	1546

The landscape of the discussions in question and the distribution of publications through countries and across publication types in reference to QII is very similar to the results within QI, namely: with Germany and Italy as the leading countries as well as with conference papers and articles being the most common types of publications. However, if these discussions include not only Industry 4.0 but also Competencies 4.0, then countries such as the United States and China can also be treated as world leaders in this respect. It is interesting to note that the leading scientific fields in the discussions on Industry 4.0 and Competencies 4.0 are engineering and computer science. This debate is also carried out in the broadly understood field of management and social sciences.

The results of Query III (QIII) presented in Table 6 below depict the quantitative distribution of scientific discussions on Competencies 4.0 across scientific fields or subject areas in reference to articles and conference papers. The choice of these two types of publications was made for the analysis because most of the discussions in question are carried out in these publication types (see Table 1). Accordingly, 4739 documents were taken into consideration: 2345 articles and 2394 conference papers. The search was carried out on the basis of publication titles, keywords and abstracts. This approach guarantees that retrieved documents treat the discussion on Competencies 4.0 as one of the key aspects of the whole Industry 4.0 concept. It is also very important to note that Query III takes into consideration exactly defined competencies and skills, so it means that the data obtained refers to sources specifically targeting the issues of Competencies 4.0 in the context of Industry 4.0, and not merely mentioning them.

Table 6. Query III: Competencies 4.0 across 5 top scientific fields or subject areas. [1]

Query III				
Scientific Field or Subject Area	**Number of Publications Incl. QIII.1** [2]	**Number of Publications Incl. QIII.2** [3]	**Number of Publications Incl. QIII.3** [4]	**Number of Publications Incl. QIII.4** [5]
Business, Management and Accounting	5	40	218	223
Engineering	4	39	169	168
Environmental Science	3	31	65	87
Decision Sciences	2	25	56	60

Social Sciences	2	15	46	53
Total (840)	9	104	354	373

Notes: [1] Set of publications = 4739 articles and conference papers as in Table 1. [2] QIII.1 = digital competencies or digital competences or technical competencies or technical competences. [3] QIII.2 = managerial competencies or managerial competences or team management or team coordination or leadership or entrepreneurship. [4] QIII.3 = cognitive competencies or cognitive competences or problem solving or complex problem solving or creativity or critical thinking or flexibility or adaptability. [5] QIII.4 = social competencies or social competences or team work or team collaboration or team cooperation or cooperation within a group or leadership or entrepreneurship or flexibility or interdisciplinarity.

The following findings can be observed from the data in Table 6:

- Out of 4739 articles and conference papers on Industry 4.0, only 840 provide a discussion on Competencies 4.0 as a key element of the Industry 4.0 concept.
- During the discussions on Competencies 4.0, the stress is mainly put on broadly understood, so-called soft and transversal skills, which can be observed from data obtained for QIII.3 and QIII.4. Interestingly enough, the discussions on digital and technical competencies are rare.
- It is also interesting to note that the trend from the above observation is also reflected in the distribution of the discussions on Competencies 4.0 across the top 5 scientific fields or subject areas. Most of the discussions are held in business and technical fields rather than in social sciences.

The results of Query IV presented in Table 7 below once again provide the number of occurrences of digital (QIII.1), managerial (QIII.2), cognitive (QIII.3) and social (QIII.4) competencies in the above-defined set of publications in order to provide a context for sub-queries which constitute Query IV. First of all, however, it shows co-occurrences of these competencies in the discussions on Competencies 4.0 in the context of the Industry 4.0 concept.

Table 7. Query IV: Occurrence and co-occurrence of Competencies 4.0 in the publication titles, keywords and abstracts.

Query IV		
Sub-Query No.:	**Sub-Queries**	**Occurrences and Co-Occurrences of Queries in a Given Set of Publications [1]**
Single Queries		
QIV.1	QIII.1	9
QIV.2	QIII.2	104
QIV.3	QIII.3	354
QIV.4	QIII.4	373
Double Queries		
QIV.5	QIII.1 and QIII.2	1
QIV.6	QIII.1 and QIII.3	0
QIV.7	QIII.1 and QIII.4	4
QIV.8	QIII.2 and Q3	14
QIV.9	Q2 and QIII.4	103
QIV.10	QIII.3 and QIII.4	275
Triple Queries		
QIV.11	QIII.1 and QIII.2 and QIII.3	0
QIV.12	QIII.1 and QIII.2 and QIII.4	1
QIV.13	QIII.1 and QIII.3 and QIII.4	0
QIV.14	QIII.2 and QIII.3 and QIII.4	14
Quadruple Queries		

QIV.15	QIII.1 and QIII.2 and QIII.3 and QIII.4	0

Note: [1] Set of publications = 4739 articles and conference papers as in Table 1.

The following conclusions can be drawn from the data in Table 7:

- In most cases, the discussions on social competencies are held in conjunction with cognitive ones (sub-query QIV.10) and managerial ones (sub-query QIV.9).
- As stated before, the discussions on digital or technical competencies are rare but if they appear, they are rather combined with social competencies (sub-query QIV.5, QIV.6, QIV.7). This means that the discussions on digital and technical competencies are put in the context of the human factor, which means, in turn, the humanistic approach in the digitalised world of Industry 4.0.
- The co-occurrence of three competencies can be rarely observed but when it happens, it refers to managerial, cognitive and social competencies (sub-query QIV.14).

The analysis of the most frequently used keywords, as identified by the authors themselves, in the whole literature on Industry 4.0 is shown in Table 8.

Table 8. Most frequent keywords.

Most Frequent Keywords	
Keyword	**Frequency**
Industry 4.0	6125
Industrial Revolutions	1721
Internet of Things	1526
Embedded Systems	1234
Manufacture	995
Artificial Intelligence	683
Automation	651
Cyber-Physical System	630
Big Data	612
Industrial Research	581

The data shows that the most frequently used keywords provided by the authors themselves relate mostly to Industry 4.0 and its characteristic features listed in the Introduction. The following graphic presentation depicts the most frequently used keywords (Figure 2).

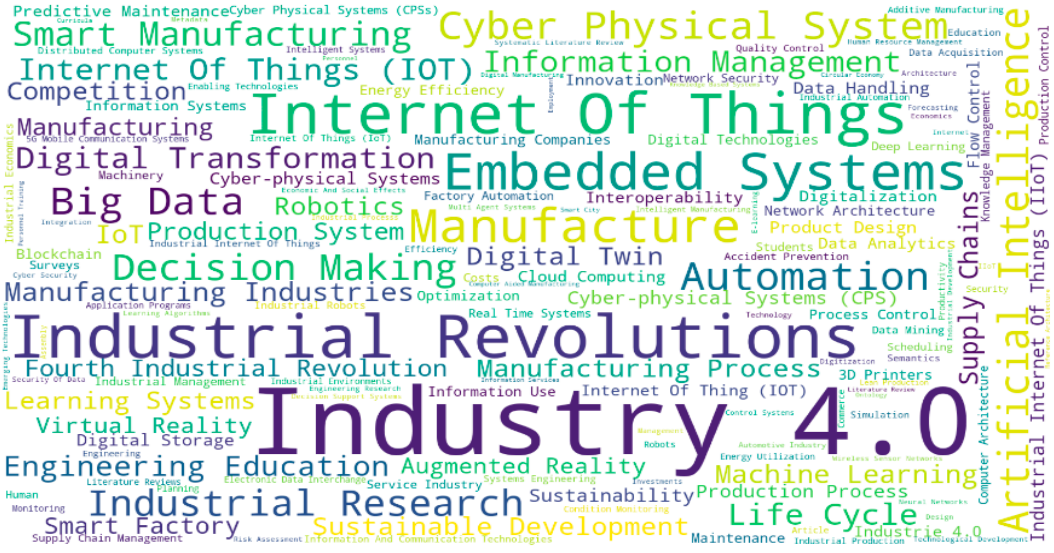

Figure 2. Frequency of keywords used in academic papers.

This visualisation also stresses the fact that most of the discussions are carried out within technical scientific fields.

Finally, the most meaningful qualitative indicator of this analysis is the presentation of the most prolific authors and publications (Table 9).

Table 9. Publications with most citations.

Authors	Title	Source Title	Number of Citations
Lee, J., Bagheri, B., Kao, H.-A.	A Cyber-Physical Systems Architecture for Industry 4.0-based Manufacturing Systems	*Manufacturing Letters* 2015, 3, 18–23	1955
Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., Hoffmann, M.	Industry 4.0	*Business and Information Systems Engineering* 2014, *6*(4), 239–242	1038
Hermann, M., Pentek, T., Otto, B.	Design Principles for Industrie 4.0 Scenarios	Proceedings of The 49th Annual Hawaii International Conference on System Sciences, Koloa, USA, 5–8 January 2016, pp. 3928–3937	982
Lu, Y.	Industry 4.0: A Survey on Technologies, Applications and Open Research Issues	*Journal of Industrial Information Integration* 2017, *6*, 1–10	884
Lee, J., Kao, H.-A., Yang, S.	Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment	*Procedia CIRP* 2014, *16*, 3–8	870
Zhong, R.Y., Xu, X., Klotz, E., Newman, S.T.	Intelligent Manufacturing in the Context of Industry 4.0: A Review	*Engineering* 2017, *3*(5), 616–630	718
Monostori, L., Kádár, B., Bauernhansl, T., (...), Sihn, W., Ueda, K.	Cyber-Physical Systems in Manufacturing	*CIRP Annals* 2016, *65*(2), 621–641	667
Wollschlaeger, M., Sauter, T., Jasperneite, J.	The Future of Industrial Communication: Automation Networks in the Era of the Internet of Things and Industry 4.0	*IEEE Industrial Electronics Magazine* 2017, *11*(1), 17–27	648
Xu, L.D., Xu, E.L., Li, L.	Industry 4.0: State of the Art and Future Trends	*International Journal of Production Research* 2018, *56*(8), 2941–2962	642
Stock, T., Seliger, G.	Opportunities of Sustainable Manufacturing in Industry 4.0	*Procedia CIRP* 2016, *40*, 536–541	628

4. Final Remarks

Although the Industry 4.0 and consequently Competencies 4.0 concept are relatively new (see Tables 1 and 4), the discussions on them have already proliferated widely across the globe. Nevertheless, German authors and Germany are still leading the way in this respect. Even if the concept of Industry 4.0, as a governmental initiative in Germany, has its various equivalents in other parts of the globe [4], it can be stated that the term "Industry 4.0" is widely used in Europe. Outside Europe, the term "4th Industrial Revolution" is preferred (see Tables 2 and 3). However, according to the data from Table 4, it was not before 2016 that this proliferation started on a substantial scale. Consequently, it does not come as a surprise that one of the most prolific authors (see Table 9), namely [24] in 2015 and [25] in 2014 still claimed that the concept of Industry 4.0 was not widely known outside German-speaking countries.

So far, most of the discussions are carried out within technical and industrial fields as well as in the world of business in reference to practical applications of the concepts in question. Accordingly, discussions on Competencies 4.0 are held in specific functional contexts rather than in a broadly understood context of education (see Tables 5 and 6).

The discussions on Competencies 4.0 are, in most cases, a part of broader debates on Industry 4.0 and its practical applications instead of being a separate field of scientific discourse (see Tables 5, 6 and 8).

Additionally, even if the topic of Competencies 4.0 does not prevail in the broader discussions on Industry 4.0 as a fundamental element (see Tables 5–7), it must be stated that it constitutes a substantial part of these discussions in some cases. The authors mainly deliberate on social and cognitive aspects of Competencies 4.0. This finding corresponds very well with McKinsey's research [13] which proves the need to shift from hard skills towards soft skills included mainly in broader categories of social and cognitive competencies in order to cater for the needs and challenges posed by the 4th Industrial Revolution (see Tables 6 and 7).

There are still relatively few more extensive sources of the discussion on Industry 4.0 and Competencies 4.0 in the form of books or book chapters (see Tables 1 and 5). However, due to fast and inevitable global trends and changes such as digitalisation and automation, even fostered and accelerated by such unexpected events as the COVID-19 pandemic, further substantial proliferation of the discussion on Industry 4.0 and Competencies 4.0 in various types of scientific sources should be expected. Moreover, there is a need to proliferate this discussion beyond business and technical fields. Social sciences and the educational sector should pick up the issue of Competencies 4.0 and the research on it and use it more extensively in order to bridge the gap between the education and business/industry sectors. Furthermore, as shown on the basis of various typologies, the concept of Competencies 4.0 is of a generic character and is applicable in various contexts, practitioners from different fields and areas can use it as a source of inspiration. This concept can be used, and actually must be used, both for curriculum development at universities as well as for recruiting processes in companies and factories.

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