SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
ORGANIZATION AND MANAGEMENT SERIES NO. 179

COMPETENCIES IN THE FACE OF CHANGES BROUGHT ABOUT BY INDUSTRY 4.0

Sandra GRABOWSKA[1*], Sebastian SANIUK[2]

[1] Silesian University of Technology, Department of Production Engineering; sandra.grabowska@polsl.pl, ORCID: 0000-0002-9014-036X
[2] University of Zielona Gora, Department of Engineering Management and Logistic Systems; s.saniuk@wez.uz.zgora.pl, ORCID: 0000-0002-0478-3466
* Correspondence author

Purpose: The purpose of this article is to identify trends and interests of researchers in the area of employee competencies in the face of changes brought about by Industry 4.0.
Design/methodology/approach: The achievements and results presented in the article were obtained from bibliometric studies conducted in Web of Science and Scopus databases. The study used dynamic literature analysis and knowledge visualization. Semantic maps of keywords were created to identify topics and contexts in which the research addresses competencies. VoSviewer software (version 1.6.16) was used to create the semantic maps.
Findings: The results obtained in the bibliometric survey confirm that the interest of researchers from all over the world in Industry 4.0 is constantly growing. In the Web of science and Scopus databases, publications on this topic continue to increase, but the vast majority of them are devoted to technology, digitization and digitalization, i.e. topics relevant to building the technical architecture of the business model. A clear research gap was identified in the area of social architecture of the business model, of which employee competency management is a component. Semantic keyword maps were created to identify topics and contexts where research is concerned with employee competency in the era of Industry 4.0.
Research limitations/implications: The literature analysis was narrowed to peer-reviewed articles published in English, indexed in the Web of Science and Scopus databases, which is a limitation of the study.
Originality/value: Original achievements obtained during the research include obtaining valuable research results on key areas linking competencies and Industry 4.0.

Keywords: competencies, Industry 4.0, Industry 5.0.

Category of the paper: research paper.

1. Introduction

The world is currently facing many changes in technological, economic and social areas. Industry 4.0 is challenging the economy and society. Academic circles are discussing the nature of these changes. Specialized research centers, universities and consulting firms are conducting studies on various aspects of the implementation of Industry 4.0 technologies and the pillars of Industry 5.0 and their consequences not only for consumers and society as a whole, but also for the future labor market, sustainable development, reducing energy consumption, increasing the resilience of the economy, etc. (Goti-Elordi et al., 2018; Zoubek et al., 2021; Vane et al., 2021).

The progressive process of digitization of all areas of the economy, which is a result of the industrial changes currently taking place, implies the need to analyze the consequences that relate to changes in the economy and society. These changes are affecting all areas of human life to an unprecedented extent. Industry 4.0 is distinguished by unlimited access to data and information, which is a competitive advantage (Bartosik-Purgat, Ratajczak-Mrozek, 2018; Birkel et al., 2019; Napoleone et al., 2020). Data providers are emerging smart factories, smart cities and smart homes, which use open socio-technological systems that connect smart machines and devices with human users in so-called cyber-physical systems (CPS). CPSs use increasingly sophisticated artificial intelligence algorithms that operate on large data sets that are collected and processed in real time, affecting physical processes across the network of relationships. In addition, the application of widespread digitization of processes in the economy brings changes in terms of increasing resource efficiency, increasing production flexibility. It also provides the opportunity to achieve a high level of sustainability, sustainable production and consumption (SPC) and reduce energy consumption. Industry 4.0 leads to changes in the structure of employment, there is a demand for new employee competencies and managers (Chaka, 2020; Arcadio, 2023; Ghassoul, Messaadia, 2023). Therefore, the main purpose of the article is to identify trends and interests of researchers in the area of workforce competencies in the face of changes brought about by Industry 4.0.

2. Materials and methods

The study adopted the Dynamic Literature Linkage Analysis method introduced by C. Colicchia and F. Strozzi (2012), as it combines Systematic Literature Review (SLR) and analysis with visualization of the bibliographic network. The search for scientific publications was conducted using the Web of Science (WoS) core collection, a database provided by Clarivate Analytics, and Scopus, a database provided by Elsevier. According to the

methodology adopted in the study, the following research stages were carried out: planning, implementation and reporting.

The subject of the analysis was to identify trends and research interests in the area of competence in the era of the Industry 4.0. Identification of topic/research areas is a critical step in the analysis. Its results may change if different search phrases and criteria are used. The search was conducted on January 15, 2023 in the Web of Science and Scopus databases. All results obtained were exported to .ods, .bib, .txt files for further use using VOSviewer software. The defined research area was converted into phrases:

- (TS=("industry 4.0")) AND TS=(competence)),
- (TS=("industry 5.0")) AND TS=(competence)).

The above phrases, in the Web of Science database, were searched in the "Topic" category, including title, abstract, keywords defined by the author(s) and keywords plus (so-called "KeyWords Plus" - words and phrases extracted from the titles of cited articles, as defined in the Web of Science database). The Scopus database was searched for title, abstract and keywords defined by the author(s). The time range of the search from January 01, 2011 to December 31, 2022 was adopted. 2011 was set as the beginning of the search, this was dictated by the fact that it was in 2011 that a group of German experts introduced a strategy for industrial development based on smart technology called Industry 4.0, while the term Industry 5.0 officially began to be used in 2021. Thus, the search timeframe 2011-2022 includes works in the field of the fourth industrial revolution, which is formed by Industry 4.0 and Industry 5.0. The results obtained were further narrowed down to scientific, peer-reviewed articles published in English.

Research using bibliometric analysis applied knowledge visualization, which includes such issues as visualization of research results. Semantic maps of keywords were created to identify the topics and context in which the research deals with competencies. VoSviewer software (version 1.6.16) was used to create the semantic maps.

3. Results and discussion

The topic competence in connection with Industry 4.0 were covered by 200 researchers in the WoS database and 160 in the Scopus database. Researchers from 60 countries, representing 217 research centers, published 216 papers, which are published 159 source titles and indexed in the WoS database. On the other hand, in the Scopus database, researchers from 49 countries, representing 172 research centers, have published 1181 papers, which are published in 98 source titles.

Among the most active researchers in the WoS database are F. Ansari (3), L. B. Liboni (3), L. O. Cezarino (3), A. Adamik (3); among the most popular titles are Sustainability (19), Technological Forecasting and Social Change (5), Journal of Technical Education and Training (4), Sensors (4); The countries from which the largest number of researchers come are Silesian University of Technology (7), University of Bergamo (5), Technical University of Lodz (4), Ministry of Science Education of Ukraine (4), Technical University of Vienna (4), Tecnológico de Monterrey (4), University de Sao Paulo (4), University of Ljubljana (4), University of Maribor (4).

Among the most active researchers in the Scopus database are V. Dwiyanti (3); among the most popular titles are Sustainability (15), Procedia Manufacturing (6), Technological Forecasting And Social Change (4), Sensors (4), Journal of Technical Education and Training (4), International Journal of Innovation Creativity and Change (4); The countries from which the largest number of researchers come are Indonesia (24), Poland (23), Germany (22), Italy (21), Spain (13), England (10), Malaysia (10); the research centers to which the most papers are affiliated are the University of Education in Indonesia (6), Silesian University of Technology (5), University of Maribor (4), University of Negeri Padang (4).

The topics of competence in connection with Industry 5.0 were covered by 54 researchers in the WoS database and 44 in the Scopus database. Researchers from 7 countries, representing 32 research centers, published 14 papers, which were published in 16 source titles and indexed in the WoS database. And in the Scopus database, researchers from 10 countries, representing 22 research centers, published 12 papers that were published in 10 source titles.

Among the most active researchers in the WoS and Scopus databases are F. Aguayo-Gonzalez (2), M. J. A. Gutiérrez (2); among the most popular titles are Industrial Crops And Products (2), Sustainability (2); the countries from which the largest number of researchers come are Mexico (3), India (2), Spain (2); the research center to which the most papers are affiliated is the University of Seville (2).

The above-described results are shown in Table 1.

Table 1.
Basic bibliometric indicators of scientific articles from the research area "Competence"

Scientific articles from 2011 to 2022 from the field of research - Competence	**Base Wos**	**Base Scopus**
(TS=("industry 4.0")) AND TS=(competence)		
Number of records	216	181
Number of researchers	200	160
Most active researchers	F. Ansari (3), L.B. Liboni (3), L.O. Cezarino (3), A. Adamik (3)	V. Dwiyanti (3)
Number of source titles	159	98

Cont table 1.

Most popular source titles	Sustainability (19), Technological Forecasting and Social Change (5), Journal of Technical Education and Training (4), Sensors (4)	Sustainability (15), Procedia Manufacturing (6), Technological Forecasting And Social Change (4), Sensors (4), Journal of Technical Education and Training (4), International Journal of Innovation Creativity and Change (4)
Number of countries	60	49
Countries from which the largest number of researchers come	Italy (27), Germany (26), Poland (25), India (16), England (14), Spain (12), Brazil (11), Mexico (10)	Indonesia (24), Poland (23), Germany (22), Italy (21), Spain (13), England (10), Malaysia (10)
Number of research centers	217	172
Research centers to which most papers are affiliated	Silesian University of Technology (7), University of Bergamo (5), Technical University of Lodz (4), Ministry of Science Education of Ukraine (4), Technical University of Vienna (4), Tecnológico de Monterrey (4), University de Sao Paulo (4), University of Ljubljana (4), University of Maribor (4)	University of Education in Indonesia (6), Silesian University of Technology (5), University of Maribor (4), University of Negeri Padang (4)
(TS=("industry 5.0")) AND TS=(competence)		
Number of records	14	12
Number of researchers	54	44
Most active researchers	F. Aguayo-Gonzalez (2), M. J. A. Gutiérrez (2)	
Number of source titles	16	10
Most popular source titles	Industrial Crops And Products (2), Sustainability (2)	
Number of countries	7	10
Countries from which the largest number of researchers come	Mexico (3), India (2), Spain (2)	
Number of research centers	32	22
Research centers to which most papers are affiliated	University of Seville (2)	

Source: own study.

Based on the results obtained by searching the WoS and Scopus databases, Figure 1 shows the growth dynamics of researchers' interest in the competency area in connection with Industry 4.0, while Figure 2 shows the growth dynamics of researchers' interest in the competency area in connection with Industry 5.0.

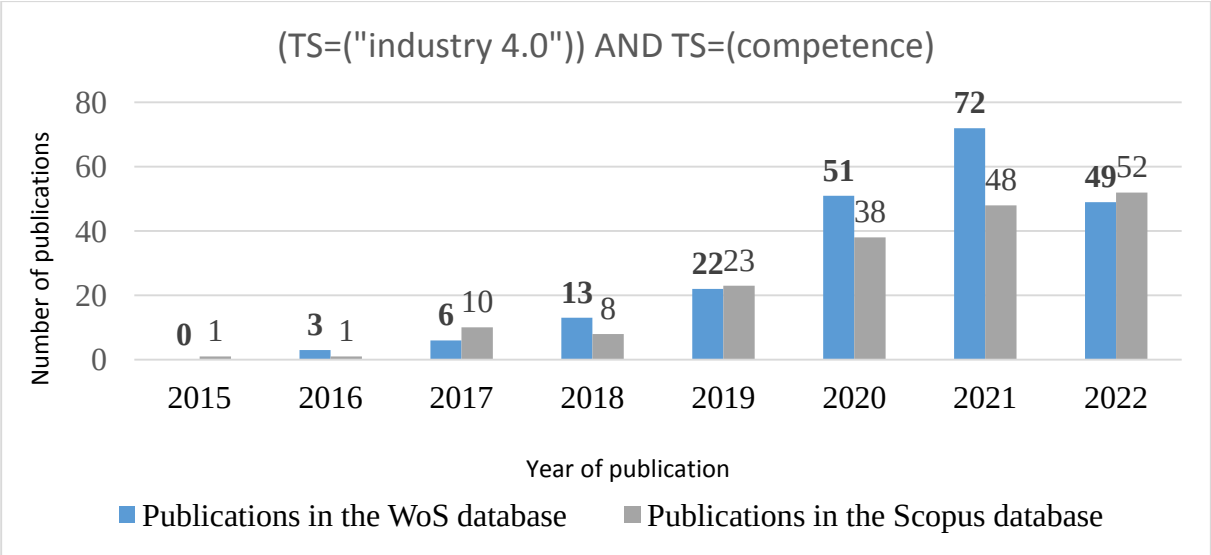

Figure 1. Growth rate of published articles in WoS and Scopus database from 2011 to 2022 for the phrase (TS=("industry 4.0")) AND TS=(competence).

Source: own study.

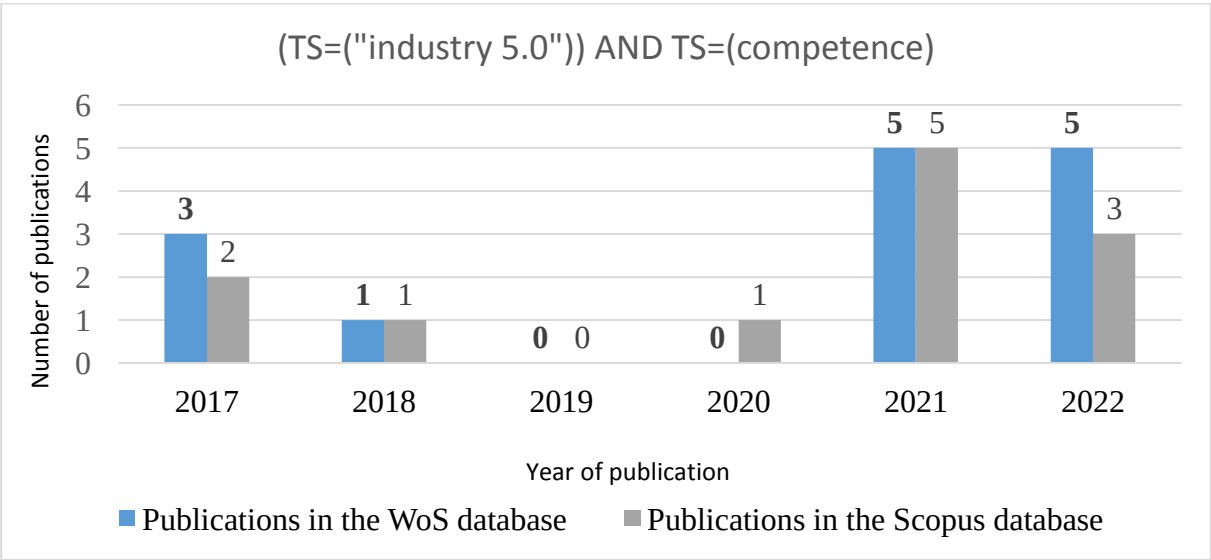

Figure 2. Growth rate of published articles in WoS and Scopus database from 2011 to 2022 for the phrase (TS=("industry 5.0")) AND TS=(competence).

Source: own study.

A review of the dynamics of the number of published scientific papers in the study area indicates that these are new topics, the interest in them is as follows:

- Competence + Industry 4.0 (TS=("industry 4.0")) AND TS=(competence) - the first publication from this area in the Scopus database appeared in 2015. In 2016, 3 publications were indexed in the WoS database and one in the Scopus database. The following year, 2017, already saw 6 publications in WoS and 10 in Scopus. The number of publications from year to year, from this area gradually increased in both databases, but it can be noted that the upward trend in the number of publications continued until 2021, and in 2022 it began to decrease. In 2021, there were

72 publications indexed in Wos and 48 in Scopus, while in 2022 it was 49 in Wos and 52 in Scopus. This situation is most likely due to the fact that in 2021 people started talking about Industry 5.0, in which a lot of attention is paid to the person/employee, so it becomes reasonable to associate competencies precisely with Industry, 5.0, and not Industry 4.0.

- Competence + Industry 5.0 (TS=("industry 5.0")) AND TS=(competence) - despite the fact that the concept of Industry 5.0 appeared in 2021, researchers had already started writing about it in conjunction with competence in 2017, at which time 3 articles were indexed in the Web of Science database, while 2 articles were indexed in the Scopus database. In the following year, 2018, one article each appeared in both databases. In 2019, no articles from the area of competence and Industry 5.0 were indexed in the databases. In 2021, when the concept of Industry 5.0 was already officially talked about, 5 articles each were indexed in the databases, while in 2022, 5 articles were of interest in the WoS database and 3 articles in the Scopus database.

Table 2 shows to which fields of science articles in the WoS database are most often assigned. And Table 3 shows to which areas of knowledge articles are most often assigned in the Scopus database.

Table 2.
WoS fields of study to which retrieved works were assigned for the phrases Competence + Industry 4.0

Place in the ranking	Fields of science defined in the Web of Science database	Search results (number of documents)
(TS=("industry 4.0")) AND TS=(competence)		
I	Management	43
II	Education Educational Research	35
III	Environmental Studies	26
IV	Business	24
V	Environmental Sciences	22
(TS=("industry 5.0")) AND TS=(competence)		
I	Agricultural Engineering	2
	Agronomy	
	Computer Science Interdisciplinary Applications	
	Environmental Sciences	
	Environmental Studies	
	Green Sustainable Science Technology	
	Multidisciplinary Sciences	

Source: own study.

Analyzing the data in Table 2, it can be seen that publications with the phrase (TS=("industry 4.0")) AND TS=(competence) were assigned to the following WoS scientific fields: management (43), education and educational research (35), environmental research (26), business (24), environmental science (22). On the other hand, publications in the phrase (TS=("industry 5.0")) AND TS=(competence) were assigned to agricultural engineering, interdisciplinary applications of computer science, environmental science, environmental research, sustainable science technology and multidisciplinary science (2).

Table 3.
Scopus knowledge areas to which the retrieved works were assigned for the phrases competency + Industry 4.0/ 5.0

Place in the ranking	Fields of science defined in the Scopus database	Search results (number of documents)
(TS=("industry 4.0")) AND TS=(competence)		
I	Engineering	74
II	Social Science	73
III	Business, Management and Accounting	55
IV	Computer Science	50
V	Energy	21
(TS=("industry 5.0")) AND TS=(competence)		
I	Computer Science	4
	Engineering	
	Social Science	
II	Environmental Science	2
	Energy	
	Agricultural and Biological Sciences	

Source: own study.

As can be seen from the data in Table 3, publications in the phrase (TS=("industry 4.0")) AND TS=(competence) were assigned to the following Scopus knowledge areas: engineering (74), social sciences (73), business, management and accounting (55), computer science (50), energy (21). On the other hand, publications in the phrase (TS=("industry 5.0")) AND TS=(competence) were assigned to: computer science, engineering, social sciences (4), environmental science, energy, agricultural and biological sciences (2).

Analyzing the keywords from all the searched publications in the WoS and Scopus database in the field of competence and Industry 4.0 (Figure 3) and in the field of competence and Industry 5.0 (Figure 4), one can see similar correlations as in the articles dealing with skills. However, it should be added that here there are new areas such as managerial competencies, leadership, technological competencies, the learning organization, empowerment, educational innovation, higher education. With the development of research towards Industry 5.0, emerging new research areas correlated with competencies are: competency-based education, engineers, sustainability competencies, personal competency development programs, affective work environment. It is noteworthy that the topic of process resilience is already appearing in publications in the area of competencies and Industry 5.0.

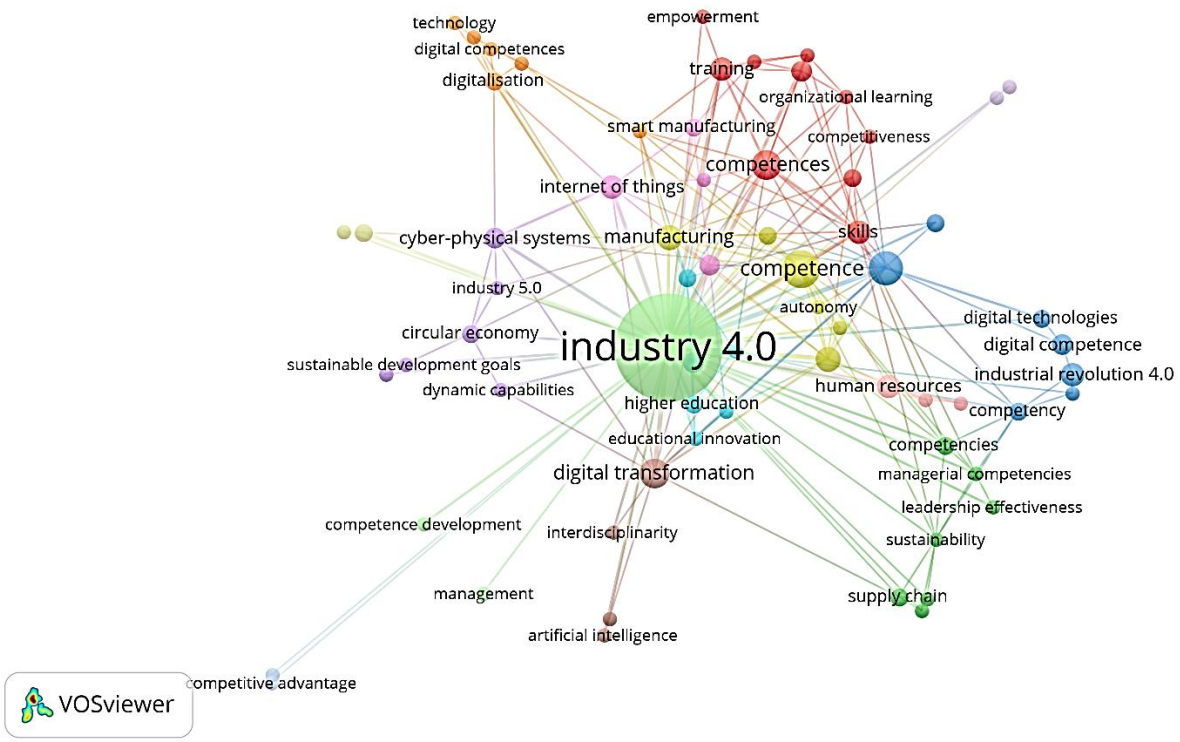

Figure 3. Keyword map for the phrase (TS=("industry 4.0")) AND TS=(competence).

Source: own study.

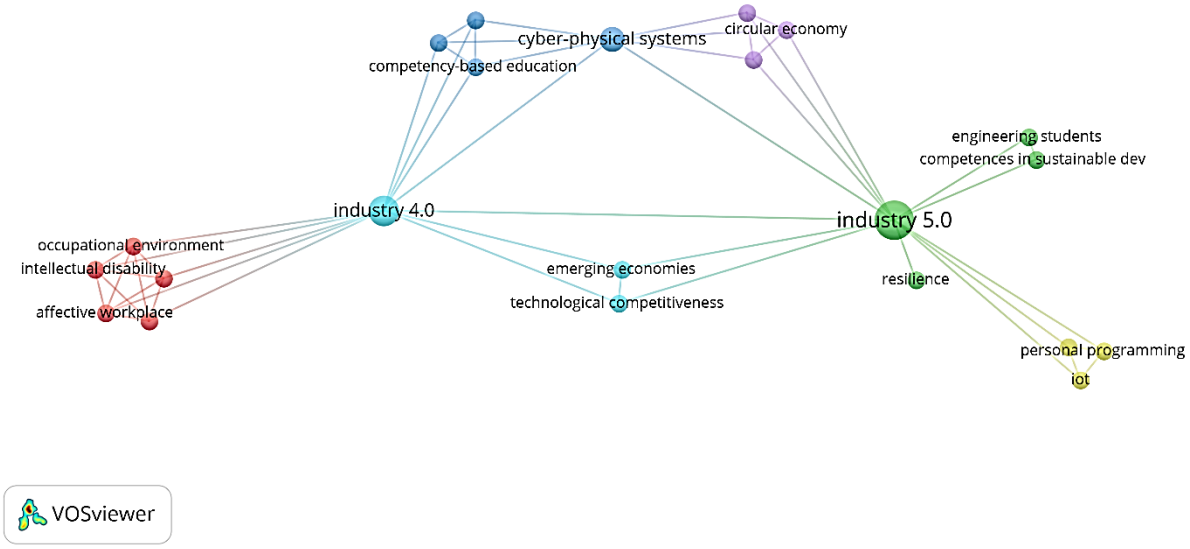

Figure 4. Keyword map for the phrase (TS=("industry 5.0")) AND TS=(competence).

Source: own study.

From the set of publications in the subject area of Competence and Industry 4.0/5.0 indexed in the WoS database, articles marked as Highly Cited Papers were selected, while ten articles with the highest number of citations were selected from the Scopus database and their content analyzed to identify what research issues they address. Several articles were duplicated in both databases, so fifteen articles were finally selected:

1. Bertola, P., & Teunissen, J. (2018). Fashion 4.0. Innovating fashion industry through digital transformation. Research Journal of Textile and Apparel, 22(4), 352-369. This article aims to provide insights into the current state of knowledge and major trends of the "fourth industrial revolution".
2. Cezarino, L.O., Liboni, L.B., Oliveira Stefanelli, N., Oliveira, B.G., Stocco, L.C. (2021). Diving into emerging economies bottleneck: Industry 4.0 and implications for circular economy. Management Decision, 59(8), 1841-1862. In this article, the authors seek to explore the relationship between the concepts of Industry 4.0 and the circular economy (GOZ) as an input to management decision-making in emerging countries. Analyzing trends in scientific production to determine the interface of the two constructs, the purpose of this article is to identify constraints to the implementation of Industry 4.0 and the circular economy in Brazil, as well as to present original frameworks and strategic paths to overcome constraints for emerging countries.
3. Chatterjee, S., Rana, N.P., Dwivedi, Y.K., Baabdullah, A.M. (2021). Understanding AI adoption in manufacturing and production firms using an integrated TAM-TOE model. Technological Forecasting and Social Change, 170, 120880 - The study aimed to identify how environmental, technological and social factors influence the adoption of Industry 4.0 in the context of digital manufacturing. The study attempted to identify the socio-environmental and technological factors that influence the adoption of embedded artificial intelligence technology by digital manufacturing and production organizations.
4. Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., Pinto, R. (2020). How do industry 4.0 technologies influence organizational change? An empirical analysis of Italian SMEs. Journal of Manufacturing Technology Management, 32(3), 695-721. This article aims to explore the organizational implications of implementing Industry 4.0 technologies, with a particular focus on operations. The article discusses these implications in two directions: organizational prerequisites and consequences of technology implementation. The results of the multiple case study show that the introduction of Industry 4.0 technology is linked to the development of a new type of job profile (i.e., "Autonomous Operative Job Profile") and higher levels of technology implementation create a greater need for non-technical competencies.
5. Dwivedi, A., Moktadir, M.A., Jabbour, C.J.C., de Carvalho, D.E. (2022). Integrating the circular economy and industry 4.0 for sustainable development: Implications for responsible footwear production in a big data-driven world. Technological Forecasting

and Social Change, 175, 121335 - The purpose of this study is to provide an original analysis of the key challenges associated with the interaction of Industry 4.0 and the circular economy for sustainable footwear production. A comprehensive literature review was conducted to identify challenges to 14.0-CE for SFP in the context of emerging economies. It was shown that a lack of competence in the concepts of Industry 4.0 and the closed loop economy hinders the goal of sustainable footwear production.

6. Fareri, S., Fantoni, G., Chiarello, F., Coli, E., Binda, A. (2020). Estimating Industry 4.0 impact on job profiles and skills using text mining. Computers in Industry, 118, 103222. The purpose of this research was to develop a quantitative measure of the readiness of employees belonging to a large company in relation to the Industry 4.0 paradigm.
7. Flores, E., Xu, X., Lu, Y. (2020). Human Capital 4.0: a workforce competence typology for Industry 4.0. Journal of Manufacturing Technology Management, 31(4), 687-703. The purpose of this article is twofold: to raise and address an important change for human capital in the future of Industry 4.0 and to propose a human-centered perspective for companies in the new industrial revolution.
8. Jiménez López, E., Cuenca Jiménez, F., Luna Sandoval, G., Ochoa Estrella, F.J., Maciel Monteón, M.A., Muñoz, F., Limón Leyva, P.A. (2022). Technical Considerations for the Conformation of Specific Competences in Mechatronic Engineers in the Context of Industry 4.0 and 5.0. Processes, 10(8), 1445 - The article proposes 15 technical considerations related to general industrial needs and disruptive technologies that serve to define the specific competencies required by mechatronic engineers to meet the challenges of Industry 4.0 and 5.0.
9. Kaasinen, E., Schmalfuß, F., Özturk, C., Aromaa, S., Boubekeur, M., Heilala, J., ... & Walter, T. (2020). Empowering and engaging industrial workers with Operator 4.0 solutions. Computers & Industrial Engineering, 139, 105678. In the article, Industry 4.0 and human-centered development, referred to as Operator 4.0, is central. The authors' vision of Operator 4.0 includes smart factories of the future that are ideally suited to workers with different skills, abilities and preferences. The vision is realized through solutions that empower workers and engage the labor community. Employee empowerment is based on tailoring the shop floor to the employee's skills, abilities and needs, and supporting the employee to understand and develop their competencies. Engaging the labor community is based on tools that allow workers to participate in the design of their work and training and share their knowledge.
10. Mazur, B., Walczyna, A. (2022). Sustainable Development Competencies of Engineering Students in Light of the Industry 5.0 Concept. Sustainability, 14(12), 7233. The purpose of this article is to examine the level and nature of sustainability competencies among students of two Lublin universities: Lublin University of Technology and Lublin University of Life Sciences. This is to make it possible to assess the students' preparedness to implement the principles of sustainable development in

their future professional activities. The research aimed to determine the relationship between the type of university and students' competencies, through a self-assessment of competencies. The conceptualization and operationalization of sustainability competencies were based on the de Haan and Cebrian models, respectively.

11. Rachmawati, I., Multisari, W., Triyono, T., Simon, I.M., da Costa, A. (2021). Prevalence of Academic Resilience of Social Science Students in Facing the Industry 5.0 Era. International Journal of Evaluation and Research in Education, 10(2), 676-683 - The purpose of the article was to prevalence of academic resilience of social science students in facing the Industry 5.0 era.
12. Simons, S., Abé, P., Neser, S. (2017). Learning in the AutFab-the fully automated Industrie 4.0 learning factory of the University of Applied Sciences Darmstadt. Procedia Manufacturing, 9, 81-88. The article describes the challenges for manufacturing and the technologies proposed by Industry 4.0. It presents a fully automated Industry 4.0 learning factory and a dedicated learning path in this manufacturing facility as a problem-based laboratory space for students and project-based courses.
13. Suarez-Fernandez de Miranda, S., Aguayo-González, F., Ávila-Gutiérrez, M.J., Córdoba-Roldán, A. (2021). Neuro-competence approach for sustainable engineering. Sustainability, 13(8), 4389 - The purpose of this article was to identify factors on which to base the neurocompetence design of an instructional engineering environment and the tendency to develop curricula within dual training models.
14. Uhlemann, T.H.J., Schock, C., Lehmann, C., Freiberger, S., Steinhilper, R. (2017). The digital twin: demonstrating the potential of real time data acquisition in production systems. Procedia Manufacturing, 9, 113-120. This paper introduces a concept based on the learning factory to demonstrate the potential and advantages of real-time data acquisition followed by simulation-based data processing.
15. Zangiacomi, A., Pessot, E., Fornasiero, R., Bertetti, M., Sacco, M. (2020). Moving toward digitalization: a multiple case study in manufacturing. Production Planning & Control, 31(2-3), 143-157 - This paper presents an analysis of multiple case studies to provide a managerial perspective for implementing a transformation path towards Industry 4.0 in the manufacturing value chain. The proposed results in terms of key challenges, typical mistakes and best practices according to the level of digital implementation, provide an overview of references that can help companies understand what are the most important issues to address in the face of adopting digital and innovative technologies.

4. Conclusion

The bibliometric analysis of global scientific works in the area of competence in conjunction with Industry 4.0 and Industry 5.0 represents an effort to rationalize and systematize existing knowledge in the field of employee competency management of smart enterprises. The analysis made it possible to show in terms of time the reconstruction of scientific productivity effects in the studied area.

The results obtained in the bibliometric study confirm that the interest of researchers, from all over the world, regarding Industry 4.0 is constantly growing. The Web of science and Scopus databases continue to increase the number of publications on the subject, but the vast majority of them are devoted to technology, digitization and digitalization. Authors pay a great deal of attention to the technological aspects and digitization in the context of challenges for businesses.

The largest number of researchers working on this issue of competence in the era of Industry 4.0 come from Italy, Germany, Poland, India, England, Spain, Brazil, Mexico, Indonesia and Malaysia. A review of the dynamics of the number of published scientific papers in this area showed that from 2017 to 2021 there was an upward trend of articles related to competency and Industry 4 0, in 2022 the number of publications began to decrease most likely because scientific articles in the field of competency and Industry 5.0 began to appear in the lanes. Published articles in this area, attributed to management, education, environmental studies, business, environmental sciences, information technology applications, sustainable science technology and multidisciplinary sciences. As indicated by the keywords defined by the authors of the publications, the articles in this area are, on the one hand, about education, soft skills, smart society, work design, and on the other hand, about the technologies of Industry 4.0 (big data, artificial intelligence, data analytics) and the pillars of Industry 5.0 (focus on the human being, the worker and his continuous development). It can also be seen that sustainability topics are gaining momentum. New areas are emerging, such as managerial competence, leadership, technological competence, the learning organization, empowerment, educational innovation, higher education. With the development of research towards Industry 5.0, emerging research areas correlated with competencies are: competency-based education, engineers, sustainability competencies, personal competency development programs, affective work environment. It is noteworthy that the topic of process resilience is already appearing in publications in the area of competencies and Industry 5.0.

In articles from the research area of Competence and Industry 4.0/5.0, the topics covered are:

- Major trends of the fourth industrial revolution;
- The relationship between the concepts of: industry 4.0 and the circular economy;

- Identification of how environmental, technological and social factors influence the adoption of Industry 4.0 in the context of digital manufacturing;
- Organizational implications of the implementation of Industry 4.0 technologies, with a focus on operations and the consequences of technology implementation;
- Development of a new type of job profile, i.e. "autonomous operative job profile";
- The lack of competence in Industry 4.0 and the circular economy, which consequently hinders the goal of sustainable production;
- The development of a quantitative measure of the readiness of employees belonging to a large company in relation to the Industry 4.0 paradigm;
- Changing human capital for the needs of Industry .4.0;
- 15 technical solutions related to general industrial needs and disruptive technologies that serve to define the specific competencies required by mechatronics engineers to meet the challenges of Industry 4.0 and 5.0;
- The human focus, referred to as the development towards operator 4.0. This includes smart factories of the future that are ideally suited to workers with different skills, abilities and preferences;
- The level and nature of sustainability competence among students at two Lublin universities: the Lublin University of Technology and the Lublin University of Life Sciences;
- The academic resilience of social science students in the face of the Industry 5.0 era;
- A fully automated learning factory and a dedicated learning path in this manufacturing plant as a problem-based laboratory space for students;
- A managerial perspective for implementing a transformation path toward Industry 4.0 in the manufacturing value chain.

An in-depth analysis of the content of publications retrieved from WoS and Scopus databases indicates that the subject matter studied is characterized by multidisciplinary specificity. This approach makes it possible to obtain a comprehensive approach to research. The analyzed areas are also characterized by a wide range of studies; they draw knowledge of research methodology, methods and tools from many sciences. In theoretical terms, the research conducted contributes to the identification of the current state of knowledge on competencies in relation to Industry 4.0 and Industry 5.0, by analyzing the evolution of the state of knowledge and trends. The main limitation of the study is based on the number of citations and popularity of publications, which cannot determine the actual contribution of scientific work to the area under study. An interesting direction for future research may be to consider the problem of adapting the education system and preparing government instruments to support today's society in rapidly adapting to widespread digitization. An important issue is the adaptation of older workers to changing jobs. Moreover, the older generation will increasingly use e-health, e-patient, e-government or e-banking, e-commerce, etc.

References

1. Arcadio, R.D. (2023). Construction Workers' Skills, Competencies, Knowledge and Job Satisfaction in Industry 4.0 Technologies. *European Journal of Business Startups and Open Society, 3(7),* 1-19.
2. Bartosik-Purgat, M., Ratajczak-Mrożek, M. (2018). Big data analysis as a source of companies' competitive advantage: A review. *Entrepreneurial Business and Economics Review, 6(4),* 197.
3. Bertola, P., Teunissen, J. (2018). Fashion 4.0. Innovating fashion industry through digital transformation. *Research Journal of Textile and Apparel*, *22*(4), 352-369.
4. Cezarino, L.O., Liboni, L.B., Oliveira Stefanelli, N., Oliveira, B.G., Stocco, L.C. (2021). Diving into emerging economies bottleneck: Industry 4.0 and implications for circular economy. *Management Decision*, *59*(8), 1841-1862.
5. Chaka, C. (2020). Skills, competencies and literacies attributed to 4IR/Industry 4.0: Scoping review. *IFLA Journal, 46(4),* 369-399.
6. Chatterjee, S., Rana, N.P., Dwivedi, Y.K., Baabdullah, A.M. (2021). Understanding AI adoption in manufacturing and production firms using an integrated TAM-TOE model. *Technological Forecasting and Social Change, 170*, 120880.
7. Cimini, C., Boffelli, A., Lagorio, A., Kalchschmidt, M., Pinto, R. (2020). How do industry 4.0 technologies influence organisational change? An empirical analysis of Italian SMEs. *Journal of Manufacturing Technology Management*, *32*(3), 695-721.
8. Dwivedi, A., Moktadir, M.A., Jabbour, C.J.C., de Carvalho, D.E. (2022). Integrating the circular economy and industry 4.0 for sustainable development: Implications for responsible footwear production in a big data-driven world. *Technological Forecasting and Social Change*, *175*, 121335.
9. Fareri, S., Fantoni, G., Chiarello, F., Coli, E., Binda, A. (2020). Estimating Industry 4.0 impact on job profiles and skills using text mining. *Computers in industry, 118*, 103222.
10. Flores, E., Xu, X., & Lu, Y. (2020). Human Capital 4.0: a workforce competence typology for Industry 4.0. *Journal of Manufacturing Technology Management*, *31*(4), 687-703.
11. Ghassoul, A., Messaadia, M. (2023, January). *Analyzing the required skills and competencies in Industrial revolution 4.0 and 5.0: A Literature Review*. International Conference On Cyber Management And Engineering (CyMaEn). IEEE, pp. 39-44.
12. Goti, A., De la Calle, A., Gil, M.J., Errasti, A., Bom, P.R., García-Bringas, P. (2018). Development and application of an assessment complement for production system audits based on data quality, IT infrastructure, and sustainability. *Sustainability, 10(12),* 4679.
13. Jiménez López, E., Cuenca Jiménez, F., Luna Sandoval, G., Ochoa Estrella, F.J., Maciel Monteón, M.A., Muñoz, F., Limón Leyva, P.A. (2022). Technical Considerations for the

Conformation of Specific Competences in Mechatronic Engineers in the Context of Industry 4.0 and 5.0. *Processes*, *10*(8), 1445.

14. Kaasinen, E., Schmalfuß, F., Özturk, C., Aromaa, S., Boubekeur, M., Heilala, J., ... & Walter, T. (2020). Empowering and engaging industrial workers with Operator 4.0 solutions. *Computers & Industrial Engineering*, *139*, 105678.
15. Mazur, B., Walczyna, A. (2022). Sustainable Development Competences of Engineering Students in Light of the Industry 5.0 Concept. *Sustainability*, *14*(12), 7233.
16. Rachmawati, I., Multisari, W., Triyono, T., Simon, I.M., da Costa, A. (2021). Prevalence of Academic Resilience of Social Science Students in Facing the Industry 5.0 Era. *International Journal of Evaluation and Research in Education*, *10*(2), 676-683.
17. Simons, S., Abé, P., Neser, S. (2017). Learning in the AutFab–the fully automated Industrie 4.0 learning factory of the University of Applied Sciences Darmstadt. *Procedia Manufacturing*, *9*, 81-88.
18. Suarez-Fernandez de Miranda, S., Aguayo-González, F., Ávila-Gutiérrez, M.J., Córdoba-Roldán, A. (2021). Neuro-competence approach for sustainable engineering. *Sustainability*, *13*(8), 4389.
19. Uhlemann, T.H.J., Schock, C., Lehmann, C., Freiberger, S., Steinhilper, R. (2017). The digital twin: demonstrating the potential of real time data acquisition in production systems. *Procedia Manufacturing*, *9*, 113-120.
20. Váně, J., Kalvas, F., Basl, J. (2021). Engineering companies and their readiness for Industry 4.0. *International Journal of Productivity and Performance Management, 70(5),* 1072-1091.
21. Zangiacomi, A., Pessot, E., Fornasiero, R., Bertetti, M., Sacco, M. (2020). Moving towards digitalization: a multiple case study in manufacturing. *Production Planning & Control*, *31*(2-3), 143-157.
22. Zoubek, M., Poor, P., Broum, T., Basl, J., Simon, M. (2021). Industry 4.0 maturity model assessing environmental attributes of manufacturing company. *Applied Sciences, 11(11),* 5151.