HRM AREAS INFLUENCED BY NEW TECHNOLOGIES OF INDUSTRY 4.0 – BIBLIOMETRIC ANALYSIS

NATALIA VRANAKOVA[1], ZDENKA GYURAK BABELOVA[1]

[1]Slovak University of Technology in Bratislava, Faculty of Materials Science and Technology in Trnava, Trnava, Slovakia

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natalia.vranakova@stuba.sk

Industry 4.0 marks a major transformation driven by digitization, automation, and smart technology integration in production, significantly impacting human resources and reshaping work environments and employee management practices. Both, employees and managers must adapt to these technological shifts, which alter traditional approaches to core areas of human resource management, presenting new challenges and opportunities. This article provides a bibliometric analysis that evaluates scientific literature on Industry 4.0 and key HR areas, such as employee education, motivation, and adaptation. The analysis, based on Scopus-indexed publications, summarizes insights in this field. The primary finding emphasizes a shift in necessary employee skills, highlighting a pressing need for updated competencies in response to Industry 4.0 advancements.

KEYWORDS

adaptation, bibliometric analysis, education, Industry 4.0, motivation, training

1 INTRODUCTION

Digital transformation in the sense of the fourth industrial revolution - Industry 4.0 mainly affects the production and industry sector by using and implementing modern technologies, automation and intelligent systems. The aim of this concept is to increase efficiency, rationalize and optimize production processes, and the result is cost reduction, increased flexibility and maintaining the competitiveness of companies. The key elements of Industry 4.0 include the Internet of Things, big data and data analysis, artificial intelligence, robotics, cobotization and automation, cloud solutions and the like. There are several reasons why organisations decide to implement new technologies. Increasing efficiency and productivity can be included among the most important, as process automation allows to minimize errors, speed up the production process and at the same time reduce the need for manual work. As supply outweighs demand in today's market, Industry 4.0 offers a better ability to respond to changing market conditions and respond more quickly to either changing customer needs or completely new needs. New technologies also make it possible to increase the quality of products and reduce costs due to the reduction of non-delivery. Automation and the use of robots, in turn, eliminate monotonous tasks, increase safety and ergonomics in the workplace and improve the working conditions of employees. Even though Industry 4.0 brings a high degree of automation and digitalization, the human factor, and therefore employees, play an important role in this process and are essential for the company as a whole and also for the implementation of the Industry 4.0 concept. Digital transformation fundamentally changes the way employees are managed, educated and integrated into business processes. Therefore, we consider it important to examine individual areas of human resources management and identify to what extent, or in what form Industry 4.0 will affect them.

2 THEORETICAL BACKGROUND

At the beginning of the 21st century, the concept of Industry 4.0 was formed as the fourth industrial revolution associated with digital transformation and automation of the business world, which has the customary name Industry 4.0 [Ghobakhloo 2020]. Automation of production processes results from increasing requirements for engineers, tightening of deadlines, implementation of research results into practice, planning of production processes and economy of production processes [Kmec 2018]. This is the next step in the industrial revolution, which can further transform the production flow and change the communication between people and machines, as well as the interaction between suppliers, manufacturers and customers [Suleiman 2022]. Industry 4.0 consists of several groups of technologies that form an integrated system that considers customers, operations and production systems: big data and analytics, autonomous robots, simulation, horizontal and vertical system integration, industrial Internet of Things, cyber security, additive manufacturing, augmented reality and the cloud [Saucedo-Martinez 2017].

The implementation of Industry 4.0 affects the way work is done in companies and has changed the way work is done in the modern workplace [Sony 2022]. Human work will still be needed within systems that are more automated and digitized, but people must be sufficiently prepared for the changed way of doing work [Markova 2022]. Based on the above, it is necessary to focus on human resources in the context of digitalization and automation. The processes resulting from Industry 4.0 transform traditional work procedures, but require new skills, flexibility and adaptability of employees to the constantly changing technological environment.

The gradual introduction of digitalization and automation elements allows companies to gradually adapt to the Industry 4.0 policy [Da Roit 2022]. Traditional managements are changing, learning and adapting to new technologies and processes brought about by Industry 4.0, thereby responding to the changing demands of the work environment and employees [Durana 2019]. Working within the Industrial Revolution requires a specific talent to learn new activities and procedures through adaptation to administrative tasks and specific technical tasks. Usually, this process of adaptation takes longer until the employee becomes fully competent to perform the assigned tasks in such conditions [Zulhasni 2020]. Employees and engineers must adapt to work in the Industry 4.0 environment in terms of skill requirements and the knowledge society created as a result of the use of new technologies, digitalization and automation [Sony 2020]. Regarding the processing of theoretical background from the field of adaptation in the context of Industry 4.0, the first research question was set:

RQ1: In what ways does Industry 4.0 influence the process of employee adaptation?

Given that new technologies affect the requirements for new employee skills, it is necessary to identify the set of competencies (knowledge and skills) that must be developed in vocational education to accompany the new industrial revolution, but also the importance of the integration efforts of companies, governments and universities [Kipper 2021]. On the one hand, it is necessary for governments to respond to changes in the need for competences [Bongomin 2020], but universities also play an important role in the education of future engineers,

as university professors are key in educational innovation and the commitment and coordination of several actors is required [Caratozzolo 2022]. However, the cooperation of employers is also necessary in terms of strengthening approaches to increase the necessary skills and innovative skills of the workforce [Sima 2020]. It is essential to explore what these required skills are and to identify them from a cross-disciplinary perspective [Chaka 2020]. Based on the above-mentioned theoretical starting points, we set the second research question:

RQ2: How is Industry 4.0 related to the requirements for education and training of potential and current employees?

The motivation of companies for the introduction of new technologies results mainly from challenges related to competitiveness, future viability and economic prosperity [Muller 2018]. However, companies face challenges in preparing employees for new roles in terms of training, job design and qualitative aspects of work organization and human-computer interaction [Margherita 2021]. Successful implementation also depends on the ability of companies to effectively attract and retain a workforce that will help increase efficiency in the Industry 4.0 paradigm [Verma 2021]. Changes in the characteristics of work affect the perception of the workplace by employees. As work characteristics affect job satisfaction, new conditions result in changes in individual work outcomes such as turnover intention, motivation, performance and organizational commitment [Winkelhaus 2022]. The developed theoretical background result in the third research question:

RQ3: How do changes associated with Industry 4.0 affect employee motivation?

3 METHODOLOGY

To perform a bibliometric analysis, we chose publications indexed in the Scopus database. Analysis was performed through a combination of author keywords and "AND" and "OR" conditions. The keyword "Industry 4.0" was searched with the AND condition in the combination of the keywords "adaptation", "motivation", "education", "training" with mutual OR conditions.

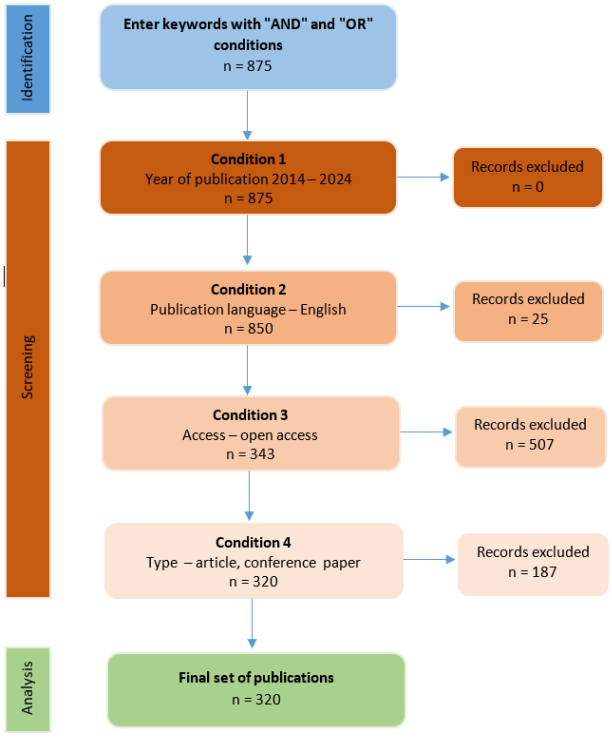

Figure 1. Procedure for selecting publications (own elaboration according to [Salvadorinho 2021])

Articles containing the keyword "Industry 4.0" and at least one of the specified areas of human resource management were filtered out. Subsequently, we expanded the filtering in the following way: year of publication 2014 – 2024; articles with open access, English language, and type of publication – article or conference paper. A total of 320 documents were filtered. The procedure according to the PRISMA approach is also shown in the following Figure 1.

Based on the data in Figure 1, we can conclude that the basic set consisted of 875 publications from the entered keywords. Subsequently, after ongoing filtering, the final set consists of 320 publications that meet the specified criteria. When evaluating the research questions, we proceeded in such a way that, within the individual areas of human resource management, we filtered the given keyword together with the condition of the keyword "Industry 4.0", i.e. for RQ1: "adaptation" and "industry 4.0"; RQ2: training" or "education" and "industry 4.0"; RQ3: "motivation" and "industry 4.0". The final selection of publications for the evaluation of research questions was based on the study of the title of the publication and its abstract.

Basic scientific methods such as comparative analysis and synthesis, induction and deduction were used in the processing of the article. The critical analysis and synthesis was based on a rigorous review of the available literature and the unification of available knowledge in order to identify contexts and theories.

4 RESULTS

Before the actual evaluation of the research questions, we focused on the analysis of the frequency of the final set of publications, as well as on the countries of origin of the articles and conference papers. The analysis of the frequency of publications is shown in the following Figure 2.

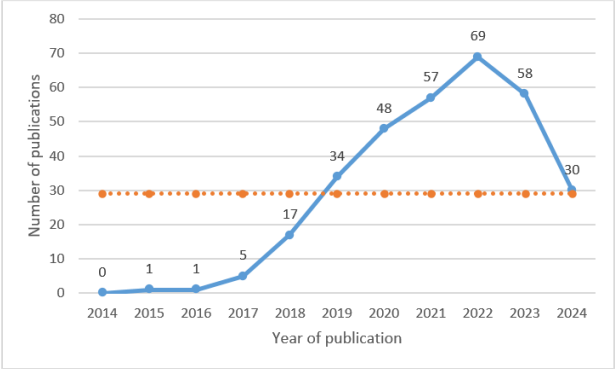

Figure 2. Analysis of publications in terms of frequency (own elaboration)

According to the data in Figure 2, out of a total of 320 publications, the most were published in 2022, a total of 69. From 2018 to 2022, we can observe a constant increase in the number of publications, while in 2023, the number decreased (58 publications). On the other hand, researchers began to be interested in the issue of Industry 4.0 in the context of human resource management in 2015. The average number of publications (shown by the orange line) is 29. The following Figure 3 shows the geographical affiliation of the analysed publications.

Figure 3 shows the countries of origin in which more than 10 publications in the field of the addressed issue were published in the Scopus database. We can state that Italy has the largest representation - a total of 32 publications, followed by Germany, the United Kingdom, Poland and Spain. Subsequently, we continued with the analysis carried out in the VOSviewer software (Figure 4) focused on the keywords of the filtered 320 publications.

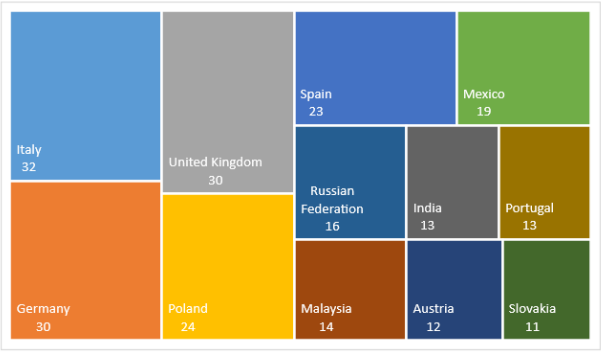

Figure 3. Analysis of publications from the perspective of country of origin (own elaboration)

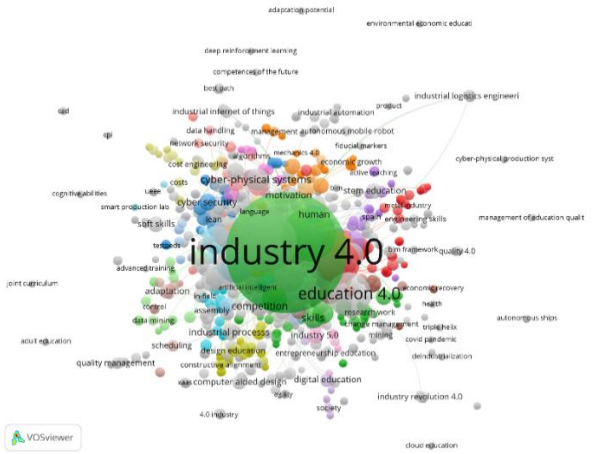

Figure 4. Co-occurrence analysis of keywords (own elaboration)

The VOSviewer analysis (Figure 4) contains a total of 2095 author keywords analysed, divided into 69 clusters and there are 25064 links. The size of the nodes represents the importance of the given element, and the colours represent the individual clusters. Among the most important nodes, which are presented by their size, are the following: industry 4.0, education 4.0, human, e-learning, learning factory, augmented reality, virtual reality, employment, sustainability.

4.1 *Evaluation of RQ1*

The first research question was: In what ways does Industry 4.0 influence the process of employee adaptation?

Based on the filtered publications with the keywords "adaptation" and "industry 4.0" and other conditions (Figure 1), we have 16 publications available. By studying and analysing them, we selected the most relevant ones, regarding the problem being solved.

The development of digital technologies leads to Industry 4.0, which requires adaptability and the ability to quickly respond to new challenges and adapt to these changes [Monti 2024]. It is often impossible to replace the entire machinery due to cost. However, smart manufacturing requires adaptation of existing machines and equipment such as CNC, machining tools and the like [Slowik 2023]. However, whether it is new technologies or a less costly modernization, a person appears in the entire process whose task is to adapt to new technical and technological challenges.

In general, more highly specialized employees are needed, while at the same time broader and more adaptable skills are required. It is important that companies choose the right strategy when adapting employees to new technologies, because Industry 4.0 is not only a matter of industrial policy, but has broad social and environmental consequences, and active management of the transition is key [Antonazzo 2021]. One of the reasons for failure to adapt to Industry 4.0 can be a lack of knowledge about technological developments. To measure the adaptation potential of employees to Industry 4.0, it is possible to use the created scale [Sozbilir 2021].

In order to adapt employees as best as possible within digitalization and automation, it is necessary for organisations to be aware of needs and build a relationship with them. The modern relationship is characterized by the fact that the employer is aware of the multidimensional needs of the employee and is therefore able to take care of the employee's financial situation, emotional well-being, work relations and atmosphere. In this direction, communication and conversations are also important, which will ensure employees feel that this is a workplace where they can achieve their goals [Nogalski 2020].

4.2 *Evaluation of RQ2*

Evaluation of second research question: How is Industry 4.0 related to the requirements for education and training of potential and current employees? is based on the analysis of publications in the Scopus database (320 publications), while from the final set of publications we selected only those that contain "training" or "education" in the author keywords and other conditions included in Figure 1. In total, 294 publications matched the search. For processing the first research question, publications were selected that corresponded to the highest degree to the addressed area based on the screening of the title of the publication and its abstract.

The Industry 4.0 era has brought many opportunities and challenges across countries and sectors, including higher education. For graduates to be ready to handle these challenges, the digital competences of lecturers and teachers must also be improved [Dang 2024]. Most publications focus on the role of business and government, but it is universities that could bring about change in the interest of digitalization and automation [Pejic Bach 2024]. The curriculum should be adapted to include the development of two basic types of skills, technical-engineering and business-managerial. In addition to hard skills, we cannot forget the need for soft skills, which are also essential [Kaczmarczyk 2024].

The relationship between educational and teaching technologies is multidimensional and complex. Open access to hardware and software tools is central to the advancement of education. Within this premise, education 4.0 defines a new educational framework in line with the digital requirements of the fourth industrial revolution [Boltsi 2024]. Companies that successfully transition to Industry 4.0 are characterized by a culture that values education, management development to understand and lead innovation, experiential learning in the workplace and strong links to education and training providers through upskilling [Hearn 2023].

Within Industry 4.0, training should be aimed at acquiring specific competencies and provide employees with opportunities to develop soft-skills. Highly specialized personnel need specific competences in certain areas [Di Sabato 2024]. To handle digitized and automated jobs, a qualified employee should have skills in the following specific areas: adaptation to change, advanced engineering, communication and connectivity, data analysis, digital skills, IT skills, problem solving and critical thinking, process knowledge and teamwork [Antonazzo 2023]. Based on other research, experts see basic digital skills as key ones, as transformation depends on digital literacy. Digital literacy, collaboration, agile work is rated as very important. Skills such as digital learning, digital interaction and digital thinking will be important to support a culture of continuous learning and adaptation. To support and drive innovation, creativity and critical thinking are important [Aichouni 2024]. Skills in robotics, Internet of Things, networks

and artificial intelligence are required to achieve the desired results. Commercial management needs skills in intelligent systems, big data and cyber security [Aranda 2023].

In general, any change, including new technologies, requires new types of knowledge and skills. When change occurs suddenly, it is difficult to plan specific and useful training. Therefore, it is important that companies quickly create education and training programs to acquire the skills that the changing reality requires [Galanti 2023]. At the same time, many professions are also changing, and demands for specific knowledge are growing not only in newly created professions, but an active approach to changes, i.e. to innovations, will be necessary. Organisations must introduce an innovative approach already in the education process itself, and a systemic approach will be necessary [Hricova 2023].

New technologies, such as augmented reality, also play a role in acquiring new and complex skills. Augmented reality helps employees learn tasks such as product assembly or maintenance. It has been shown that when using augmented reality, the acquisition of knowledge was improved compared to traditional methods [Ariansyah 2024]. Augmented reality enables specific support for employees in the production environment. When solving complex tasks, augmented reality applications help increase the efficiency and quality of employees' work [Grodotzki 2024]. Another tool can be artificial intelligence, which facilitates interdisciplinary collaboration by serving as a common platform for knowledge exchange [Abulibdeh 2024]. Another example of a learning method is the implementation of learning factories. It serves as a resource for hands-on, practice-oriented learning. The basis of this environment is a cost-effective learning factory model, complete with a digital twin (available on computers). Such an environment includes diverse modules covering engineering topics such as agile manufacturing, industrial Internet of Things, automation, machine learning, and more [Hafner 2024].

4.3 *Evaluation of RQ3*

The third research question: How do changes associated with Industry 4.0 affect employee motivation? was evaluated through publications that were filtered based on the author's keywords "motivation" and "industry 4.0" and other conditions according to Figure 1. A total of 11 publications were filtered.

The increasing adoption of digital technologies has various positive effects on society. However, many companies often rush into the introduction of technological trends without sufficient preparation and do not pay enough attention to the human factors involved in digitalization. According to the findings, it is older people who may tend to have a negative attitude and countermeasures to help them become more tech-savvy are appropriate [Eickemeyer 2021]. Organisations around the world are implementing lean systems and tools, while the adoption of Industry 4.0 technologies and approaches is improving compliance. More effective communication (through positive employee engagement and the use of gentler, more encouraging words) can help lead to better understanding and implementation of lean practices. Another of the tools is the introduction of a system for recognizing and appreciating good practices directly at the workplace [McKie 2021]. Employee orientation, which increases career motivation, is important for the implementation of Industry 4.0 elements. Through employee orientation, organisations can take care of the needs and interests of their employees with regard to their proper leadership, management and development. Among the successful examples of employee orientation, it is possible to include the reconciliation of employees' work and personal lives, respect for employees and fair remuneration. Managers who emphasize employee orientation also include in their incentive programs elements that support the career growth of employees. This suggests that these managers understand the link between focusing on employees and using career motivators to motivate them [Staffenova 2024]. In Industry 4.0, the demand for skills and knowledge is more diverse than before, and people will have to work smarter. Although paying a high salary may motivate an employee to perform his task, it may not effectively stimulate him to share knowledge effectively. On the other hand, a sense of belonging can motivate an individual to share their knowledge but does not represent work intensity [Tan 2019]. Also, in another publication, the essence of motivation is emphasized from the point of view of motivation for education and learning in the conditions of the industrial revolution [Masood 2024].

Other research has dealt with the identification of relationships between variables and factors to define important motivational elements of organizational culture [Copus 2023]. Their summary is shown in Table 1.

Table 1. Motivational elements of organizational culture [Copus 2023]

Factor	Variables
Identification of employees with their organization and its management.	Fair treatment by the company and management.
	Recognition and rewards for effort.
	Consistency between managerial decisions, actions and promises.
	Satisfaction with expressing criticism and complaints
Rationality and development	Encouragement in meeting customer requirements
	Communication and freedom of information
	Attitude towards employees and their development
	Encouragement to work on your own initiative
Group dynamics	Labour relations between departments
	Team spirit
	Working atmosphere
Internalization	Responsibility for the quality and performance of one's own work
	Consider work valuable
	Pride and satisfaction at work
	Fulfilling personal expectations from work

From the point of view of Generation Z, i.e. the youngest generation on the labour market, the most important motivational factors include a friendly atmosphere at the workplace, the possibility of professional development, adequate remuneration and a low stress index. Of these key motivators in Industry 4.0, however, significant differences can be seen by gender. A friendly atmosphere and a low level of stress were reported more often by men, while women focused on the possibility of professional development and the corresponding salary [Binczycki 2023].

An important aspect in motivation and Industry 4.0 is the view of managers and the aspects that motivate them to implement individual elements of Industry 4.0. Business focus and customer focus proved to be the motivator. A focus on sustainability emerged as a less significant motivator. Among the most

significant barriers are high investments and fear of recruitment, education and retraining of employees [Garcia-Ortega 2021]. Further research has shown that motivators include better quality of products and production, support in meeting legal requirements and a green image [Ramanathan 2023].

5 CONCLUSION

Industry 4.0 significantly changes the way human resources are managed, creating new opportunities and challenges not only for employees, but also for companies in general. Human resource management is becoming more technology-oriented and the rapidly changing environment resulting from the digitalization and automation of work procedures and work activities. In general, with increasing automation they have come concerns about job losses, changing working conditions, and widening skill gaps within different categories of employees.

However, within the analysis of various areas of human resources management, the need for new skills of employees came to the fore, and therefore the education and development of employees is one of the most significant areas that forms and complements other areas. The necessity of lifelong learning is growing due to rapidly developing technologies, while the development of both hard and soft skills is becoming indispensable. Companies require employees with more advanced technological skills, and therefore employee training becomes an important motivational element both from the point of view that employees must adapt to technological changes, but also because of the increased chance of career growth. Education provides a way for not only companies, but also employees to maintain their competitiveness on the labour market, and it is also a source of personal development and fulfilment.

Education in Industry 4.0 is not only about improving technical skills, but also about strengthening a sense of security, career possibilities and personal fulfilment. Even through education, it is possible to get rid of fears about the disappearance of the job and the subsequent uncertainty. These are therefore key factors that motivate employees to engage in modernization and digital transformation processes.

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CONTACTS:

Ing. Natalia Vranakova, PhD.

Slovak University of Technology in Bratislava

Faculty of Materials Science and Technology in Trnava

Institute of Industrial Engineering and Management

Ulica Jana Bottu 2781/25, Trnava 917 24, Slovakia

natalia.vranakova@stuba.sk

Assoc. Prof. Zdenka Gyurak Babelova, PhD.

Slovak University of Technology in Bratislava

Faculty of Materials Science and Technology in Trnava

Institute of Industrial Engineering and Management

Ulica Jana Bottu 2781/25, Trnava 917 24, Slovakia

zdenka.babelova@stuba.sk