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Technology Transfer and Human Capital in the Industrial 4.0 Scenario: A Theoretical Study

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[1]Vander Luiz da Silva
[2]João Luiz Kovaleski
[3]Regina Negri Pagani

Abstract

In face of the technological changes derived from Industry 4.0 an initial, gradual and complex process of Technology Transfer (TT) is taking place that strongly relies on the integration between university, industry, and government, mainly. In this context, in order to make the Industry 4.0 approach a reality, several requirements need to be met. One of them is the need to qualify people to work in industries. This study aimed to explore the possible changes and perspectives of human work in Industry 4.0. A systematic literature review was carried out following a structured script. 50 articles were chosen for analysis, following criteria for selection of studies. With focus on industry 4.0 a number of changes in human skills and tasks were observed. Human capital will have significant participation in the work and will undergo a redirection of tasks and learning.

Keywords: Industry 4.0. Strategic Management. Human Resources. Competencies.

[1]Federal Technological University of Paraná - UTFPR, Paraná, (Brazil). E-mail: **luizvnder@gmail.com**
Orcid id: **https://orcid.org/0000-0001-9307-7127**

[2]Federal Technological University of Paraná - UTFPR, Paraná, (Brazil). E-mail: **kovaleski@utfpr.edu.br**
Orcid id: **https://orcid.org/0000-0003-4232-8883**

[3]Federal Technological University of Paraná - UTFPR, Paraná, (Brazil). E-mail: **reginapagani@utfpr.edu.br**
Orcid id: **https://orcid.org/0000-0002-2655-6424**

Introduction

Throughout history, people and industries have witnessed multiple industrial revolutions, which have occurred gradually, beginning with the mechanization of production enabled by the steam engine, followed by the introduction of mass production and automation of production processes (Haddara; Elragal, 2015).

Recently, numerous questions have been raised about the upcoming industrial revolution, named by the Germans as Industry 4.0 (Lee; Kao; Yang, 2014), which aim is to create industries with integrated intelligent processes characterized by adaptability and efficiency of productive resources (Jasiulewicz-Kaczmarek; Saniuk; Nowicki, 2017).

According to Hecklau et al. (2016), from the integration of automation and process digitization, Industry 4.0 aims to create a diversity of opportunities for industries. Nevertheless, it also triggers a series of issues, some of them inconclusive yet.

Industry 4.0 is a recent approach, especially for emerging countries. Thus, in order for its objectives to be applied in the industries, these countries, the process of Technology Transfer (TT) must take place, strongly involving the integration between university, industry, and government, and technology providers and specialists. The technology encompasses two main components, the physical component (equipment) and the knowledge (Kumar; Kumar; Persaud, 1999).

In this context, in order to make the approach of Industry 4.0 a reality, several requirements, which are prior to, as well as embedded into the TT process, need to be met. One of them is the need to qualify people to work in manufacturing industries through the technology transfer (knowledge). According to Spath et al. (2013), an essential requirement for Industry 4.0 is the qualification of people, whose participation will be vital, with no substitution of human labor for artificial intelligence taking place. What will occur is a task redirection, that is, people will perform other tasks, such as the programming of robots on assembly lines, system operations, supervision and decision-making (Singh; Sellappan; Kumaradhas, 2013).

In Park and Lee’s concept (2017), in the Industry 4.0 scenario, the management of human resources is one of the most important elements. For Becker and Sterm (2016), in Industry 4.0, human work will be modified, and the changes to be made still requires more scientific discussion, which highlights the importance of studies on this regard.

In this study the following question is presented: What competencies are needed for human capital, in order to train people for work and to facilitate the TT process in the Industry 4.0? In view of the presented research problem, this study aimed to explore the set of changes and perspectives of human work in Industry 4.0, based on a systematic literature review.

This paper is structured as follows: The introduction presents the contextualization of the central theme and other correlated themes, as well as the problematization and objective of the study. The second and third sections present the theoretical framework on TT and Industry 4.0, respectively. The fourth section presents the methodological procedure used in carrying out this research. The fifth section presents the results of the systematic literature review and discussion. In the sixth and final section, the conclusions are presented.

Technology Transfer

Technology encompasses two main components, the physical component (products, tooling, equipment, and processes) and the informational component (marketing, production, skilled labor and functional areas of the industry) (Kumar; Kumar; Persaud, 1999). Researchers also classify knowledge as an integral component of technology. Technology is understood as a complex concept, presenting implicit, codified and/or explicit knowledge (Pagani et al., 2016).

According to Seaton and Cordey-Hayes (1993) and Davenport (2013), TT is the process of promoting the transfer of results, such as knowledge, devices and/or artifacts between organizations. Hameri (1996) defines TT as the process aimed at disseminating and/or acquiring knowledge and/or experience and/or correlated artifacts.

TT is a set of processes aimed at disseminating and retaining technologies to stakeholders (Silva; Kovaleski; Pagani, 2018). When a tangible technology is transferred, other elements should also accompany these processes, such as knowledge, experience and technical support.

The TT process basically involves two minimum conditions, the transferor who is responsible for sharing the technologies, and the receiver, who must be able to absorb the shared technologies (Takahashi, 2005). This process is extremely complex and is widely discussed by the scientific community, since it includes theoretical and applied studies related to the analysis of barriers in TT, the proposals of TT models, the facilitators and/or inhibitors of TT, and the complex University (Academy), Industry and Government (States) relationship for TT, among other subjects.

The University, Industry and Government relationship is portrayed one the Triple Helix Model (Figure 3). This model was developed from the evolution of innovation systems, which covered two other models, the Static Model (Figure 1) and the Laissez-Faire Model (Figure 2) (Etzkowitz; Leydesdorff, 2000).

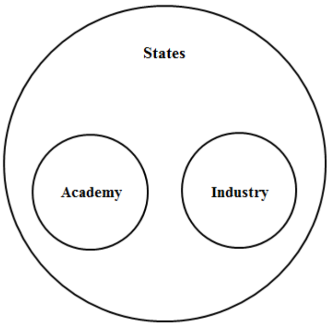

Figure 1. Static Model. Source: Etzkowitz e Leydesdorff (2000).

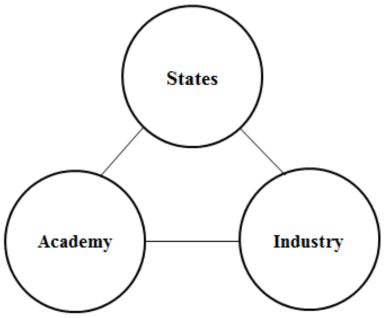

Figure 2. Laissez-Faire Model. Source: Etzkowitz e Leydesdorff (2000).

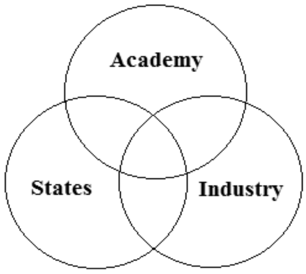

Figure 3. Triple Helix Model. Source: Etzkowitz e Leydesdorff (2000).

Essentially, in the Static Model the government encompasses university and industry and drives their relationship, the Laissez-Faire Model establishes a strong relationship between university and industry, and the Triple Helix Model configures the overlap of institutional spheres and the origin of emerging hybrid organizations (Etzkowitz; Leydesdorff, 2000), whose spheres interact independently (Saad; Zawdie, 2005). Through the Triple Helix Model, it is possible to evaluate how the TT occurs between university, industry, and government.

Industry 4.0

The term Industry 4.0 was first used in Germany during the Hannover Fair in 2011, and today it has favored the generation of numerous scientific discussions (Drath; Horch, 2014).

As a precursor to the term Industry 4.0, Germany has been conducting changes in the industrial scenario in recent years, based on production and innovation enabled by Cyber-Physical Systems (CPSs) (Lee; Kao; Yang, 2014). According to Lee (2008), CPSs consist of digital integrations with physical processes, where integrated computers and networks monitor and control physical processes. For Lalanda, Morand and Chollet (2017), Industry 4.0 is based on the use of new production techniques, new materials and diversified application of digital technologies.

By means of CPSs and other technologies, intelligent processes provide fast responses to changes in production and to faults that may occur throughout the industrial production chain (Haddara; Elragal, 2015; Jasiulewicz-Kaczmarek; Saniuk; Nowicki, 2017). Industry 4.0 requires an effective integration of equipment, people, processes, and products (Gebhardt; Grimm; Neugebauer, 2015; Haddara. Elragal, 2015), providing competitive advantages such as cost and time efficiency in production and product quality improvement (Albers et al., 2016).

Overall, industries will be positively affected by changes arising from Industry 4.0. In Germany, the automotive and food industries, as well and industries producing components and systems stands out (Rüßmann et al., 2015). According to Gorecky et al. (2014), the automotive sector is one of the leaders in the adoption of technologies such as the Internet of Things (IoT) and cyber-physical systems.

Industry 4.0, also known as the fourth industrial revolution, industry of the future or intelligent industry, encompasses nine technology based pillars, highlighted by Rüßmann et al. (2015): High volume of data for analysis; Autonomous robots; Simulation; Horizontal and vertical system integration; Internet of Things; Cybersecurity; Cloud computing; Additive manufacturing, and; Augmented reality. These pillars are described as follows.

Pillar 1: Big Data

The use of Big Data in analyses has recently emerged in some industries, aiming to improve production and product quality, ensure equipment efficiency and assist in real-time decision making (Rüßmann et al., 2015).

Big Data is a set of data processed with analytical technology, which includes unstructured data and without compatible formats, such as social network service data, blog data, news data, photos, among others (Park et al., 2017). That way, it is possible to provide personalized services to clients, assist in decision-making processes, among other advantages (Witkowsk, 2017). According to the author, Big Data encompasses four dimensions, volume, variety, velocity and value. Associating the four dimensions, Big Data assists mainly in decision-making processes (Rüßmann et al., 2015, Witkowsk, 2017).

Pillar 2: Autonomous Robots

Robots are machines developed for the purpose of performing specific tasks autonomously or by means of remote control commands (Ullah et al., 2016).

Robots present different degrees of autonomy according to each one's purpose and need of development. In this context, while some robots are programmed to perform repetitive, standardized, and precise tasks, other robots are extremely flexible as to the orientation of the object and/or the task to be performed (Singh; Sellappan; Kumaradhas, 2013).

In industry 4.0, the participation and intensification of autonomous robots in industries is a reality (Rüßmann et al., 2015). This occurs for several reasons, one of them being the fast technological advance (Tasevski; Nikolić; Mišković, 2013).

Singh, Sellappan e Kumaradhas (2013) describe in their study the advantages of using robots in industries, as a work factor, in the following categories:

– Productivity: i) Robots develop more accurate and high quality work; ii) Robots rarely make mistakes; iii) They produce more products in a shorter amount of time; (iv) They work at a constant and uninterrupted speed; v) They are faster in performing tasks;

– Work safety: i) Robots can perform dangerous tasks; (ii) They can work in places hazardous for humans, such as places with poor lighting or tight spaces, and; iii) They are capable of lifting heavy loads without the risk of accidents;

– Time saving: i) Robots save time due to higher productivity for a certain period, and;

– Money saving: (i) Robots reduce wasted raw material due to high production accuracy, and; ii) Ensure greater financial returns to long-term industries.

Pillar 3: Simulation

Simulation is the process of creating and designing a real or imaginary system by using physical or mathematical models, or models of other kind, for modeling, in order to evaluate and predict system behavior (Rodič, 2017).

The use of simulation in conjunction with other computational resources and three-dimensional tools enables the design of production processes and products simultaneously (Wang et al., 2016), and brings advantages such as cost reduction, product or process quality enhancement, and adequate knowledge management, among others (Rodič, 2017). In industries, simulations of products, materials and/or processes in three-dimensional scenarios are already developed, but over the years they will intensify and encompass data in real time (Rüßmann et al., 2015).

In order to meet the needs of intelligent industries, where computer systems can be used to design, simulate and monitor integrated physical processes, new simulation tools are developed, whose main objective is to create increasingly accurate virtual maps of reality and facilitate the decision-making process (Gebo Cermex, 2016).

Pillar 4: Horizontal and Vertical System Integration

A reality nowadays is that industries, suppliers, and customers are not totally interconnected. In industry 4.0, the integration of global data will generate value chains involving industries, departments and other internal and external context elements (Rüßmann et al., 2015).

Pillar 5: Internet of Things

The Internet of Things (IoT) consists of intelligent communication systems using IP addresses, which allows the interconnection of objects to the network (Anderl, 2014; Haddara; Elragal, 2015).

Although in industries some technologies are already connected to machines and the network, with the internet of things, a greater number of devices and sensors will be incorporated into the processes and connected to the network, providing real-time responses (Rüßmann et al., 2015). According to Porter and Heppelmann (2014), intelligent products connected to the network offer exponential expansion opportunities for new features. The Internet of Things presents itself as an important technology and should reflect on economic opportunities (Hofmann; Rüsch, 2017).

Pillar 6: Cybersecurity

As a result of the greater incorporation of data and information into the digital environment, in Industry 4.0 system security will be indispensable (Rüßmann et al., 2015). In Intelligent Industry, a complex and efficient approach to cybersecurity should be adopted to protect data, information, knowledge and/or other intellectual elements (Annunziata; Biller, 2014).

Pillar 7: Cloud Computing

With the increase in data and information sharing, the intelligent industry will require cloud technologies with a higher performance, in order to provide appropriate processing, storage, and connectivity (Rüßmann et al., 2015).

Pillar 8: Additive Manufacturing

Industries already employ principles of the manufacture of additives, such as 3D printing of prototypes; however, it will also be used in the production of small volumes of batches of custom products (Rüßmann et al., 2015).

In industry 4.0, new production techniques will be developed and intensified, such as printing in 3D technologies, which offers greater flexibility in creating product prototypes faster and with better costs, as well as benefit product development stages, prototyping, and production (Annunziata; Biller, 2014).

Pillar 9: Augmented Reality

In this pillar, information about services to be treated in the industries, such as selecting parts from a warehouse or product repair instructions, will be displayed to workers through augmented reality devices (Rüßmann et al., 2015).

4 Methodi

From the point of view of the problem approach, the research is classified as qualitative (Silva, Menezes, 2005) as it aimed at the interpretation and description of phenomena related to the configuration of human work in the Industry 4.0 scenario.

Considering its objectives, the research is classified as exploratory, since it aimed to provide greater familiarity with the problem under study (Gil, 2008).

From the point of view of technical procedures, it is classified as a bibliography exploratory research, since it was elaborated from studies disseminated in periodicals (Gil, 2008).

To explore the current reality and perspectives on human work in the Industry 4.0 scenario, a systematic literature review was carried out, using the protocols of Pagani, Kovaleski and Resende (2015), which presented the following steps: i) Selection of bibliographic databases; ii) Establishing keywords and combinations of keywords; iii) Defining search criteria in databases; iv) Performing searches in the databases; v) Eliminating duplicate articles; vi) Defining and apply criteria to eliminate articles incompatible with the proposed theme; vii) Qualifying articles from the calculation and analysis of InOrdinatio values; and viii) Full reading of selected articles.

According to the objectives and intention of the research, the selected keywords were "Industry 4.0", "Smart Manufacturing", "Fourth Industrial Revolution", "Smart Industry", "Human", "Worker" and "Technology Transfer", which were then combined and explored in some databases.

Subsequently, combinations of keywords and search criteria were defined in the Science Direct, Scopus, and Web of Science databases (Chart 1, 2 and 3, respectively).

Chart 1. Relevant information for systematic literature review.

<table>
<tr><th rowspan="2">Keyword</th><th colspan="4">Database - Science Direct</th></tr>
<tr><td>"Human"</td><td>"Employee*"</td><td>"Worker*"</td><td>"Technology Transfer*"</td></tr>
<tr><td>"Industry 4.0"</td><td colspan="4" rowspan="4">Procedures: i) Keywords in Abstract-Title-AND-Keywords, and; ii) AllYears.</td></tr>
<tr><td>"Smart Manufacturing"</td></tr>
<tr><td>"Fourth Industrial Revolution"</td></tr>
<tr><td>"Smart Industry"</td></tr>
</table>

Chart 2. Relevant information for systematic literature review.

Keyword	Database – Scopus			
	"Human"	"Employee*"	"Worker*"	"Technology Transfer*"
"Industry 4.0"	Procedures: i) Keywords in Abstract-Title-AND-Keywords, and; ii) AllYears.			
"Smart Manufacturing"				
"Fourth Industrial Revolution"				
"Smart Industry"				

Chart 3. Relevant information for systematic literature review.

Keyword	Database - Web of Science			
	"Human"	"Employee*"	"Worker*"	"Technology Transfer*"
"Industry 4.0"	Procedures: i) Keywords in Title ("Industry 4.0","Smart Manufacturing", "Fourth Industrial Revolution", "Smart Industry") AND Topic ("Human", "Employee*", "Worker*", "Technology transfer*"), and; ii) AllYears.			
"Smart Manufacturing"				
"Fourth Industrial Revolution"				
"Smart Industry"				

The bibliographic databases selected were: Science Direct, Scopus, and Web of Science. The choice was based on the fact that these bases presented the greatest amount of articles on the subject researched, even containing articles present in other databases.

Searches were conducted from the combinations of keywords and definition of criteria. The resulting articles were grouped in a reference manager. In order to select only articles directly related to the research theme, the following filtering procedures were applied: i) Eliminate duplicated articles; ii) Eliminate articles published in conferences, and iii) Eliminate articles unrelated to the topic under study. From the application of the filtering criteria, for the final result of articles, the Phase 7 of the Methodi Ordinatio (Pagani; Kovaleski; Resende, 2015), named InOrdinatio, was performed in order to qualify and organize articles according to scientific relevance, equating impact factor, year of publication and number of citations of each article. The InOrdinatio values were organized in Microsoft Excel® spreadsheets, enabling the qualification and selection of articles.

Results and Discussion

General Analysis of Publication on Industry 4.0 and TT

The results obtained in the searches for the keyword combinations in each of the three databases are described in Table 1, 2 and 3, respectively.

Table 1. Results for systematic literature review.

Keyword	Database - Science Direct				
	"Human"	"Employee*"	"Worker*"	"Technology transfer*"	Result
"Industry 4.0"	23 results	5 results	8 results	0 result	36
"Smart Manufacturing"	6 results	1 result	2 results	0 result	9
"Fourth Industrial Revolution"	4 results	1 result	1 result	0 result	6
"Smart Industry"	1 result	1 result	0 result	0 result	2
Result					53

Table 2. Results for systematic literature review.

Keyword	Database – Scopus				
	"Human"	"Employee*"	"Worker*"	"Technology transfer*"	**Result**
"Industry 4.0"	108 results	31 results	32 results	10 results	181
"Smart Manufacturing"	44 results	8 results	10 results	2 results	64
"Fourth Industrial Revolution"	22 results	6 results	4 results	3 results	35
"Smart Industry"	6 results	1 result	1 result	0 result	8
Result					288

Table 3. Results for systematic literature review.

Keyword	Database - Web of Science				
	"Human"	"Employee*"	"Worker*"	"Technology transfer*"	**Result**
"Industry 4.0"	8 results	0 result	2 results	0 result	10
"Smart Manufacturing"	6 results	0 result	0 result	0 result	6
"Fourth Industrial Revolution"	2 results	1 result	1 result	0 result	4
"Smart Industry"	0 result	1 result	0 result	0 result	1
Result					21

Among the databases researched Scopus presented the highest result of articles compared to Science Direct and Web of Science.

The respective results of articles found are described in Tables 1, 2 and 3, and organized in Table 4.

Table 4. Results for systematic literature review

Database			TOTAL
Science Direct	***Scopus***	***Web of Science***	
53 results	288 results	21 results	362

A total of 260 articles (elimination of duplicates) were obtained. The filtering processes applied are described in Table 5.

Table 5. Filtering of articles.

Filtering procedure	Gross total of articles	Total articles after filtering
Conference articles	260	135
Unrelated articles to the scope of the study	135	**88**

The portfolio of 88 articles was submitted to the seventh phase of Methodi Ordinatio, called InOrdinatio. From this total, 50 articles were selected for content analysis using the information presented in Table 6.

Table 6. Selection criteria for articles for the systematic literature review.

Description	Total
Total articles submitted to Methodi Ordinatio	88
Articles with best InOrdinatio results	**50**
Items discarded due to low InOrdinatio results (zero values for impact factor and citations in the literature, predominantly)	26
Articles unaccessible to researchers	12

The number of articles selected was significant for discussions on human work in the Industry 4.0 Scenario.

Not all articles selected address exclusively the subject qualification of people for work and related aspects. However, even in other matters related to Industry 4.0, some of the articles provide relevant contributions. Some studies deserve special mention, such as the one by Hecklau et al. (2016), who identified human competencies for work in Industry 4.0, classifying them into four categories, professional, methodological, social and personal competencies, as well as the study by Romero et al. (2016), in which the authors describe the key competencies needed to operate cybernetic and automated systems.

The period of publication in scientific journals stands out among the data identifying the selected articles. Figure 4 shows the articles grouped according to their respective publication years.

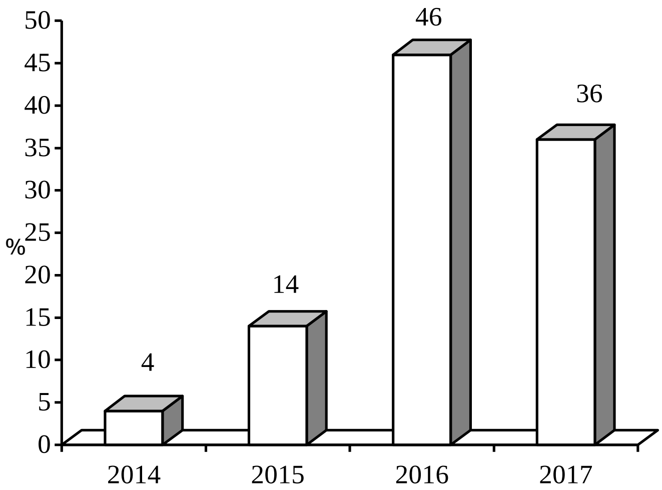

Figure 4. Distribution of articles, according to the year of publication.

It was observed that most articles were published in periodicals in 2016 (46%), although the year 2017 cannot be included in its entirety in the study period (first half term), which would certainly increase the number of publications.

While setting the "all years" option during the searches in databases, only current articles were found, that is, published in the last four years. This is due to the fact that the term Industry 4.0 has recently emerged in Germany, which gives rise to a number of issues, some of them little explored and inconclusive.

Regarding the citation numbers of the studies in the literature, a low citation index was observed. This is due to the vast majority of articles being recent, mainly published in 2016 and 2017. From the elaboration of a portfolio of 50 articles (resulting from the qualification of 88 articles), the representativeness of countries in the production of studies was verified; that is, it was possible to identify the countries with the largest number of representatives (authors of articles), as described in Figure 5.

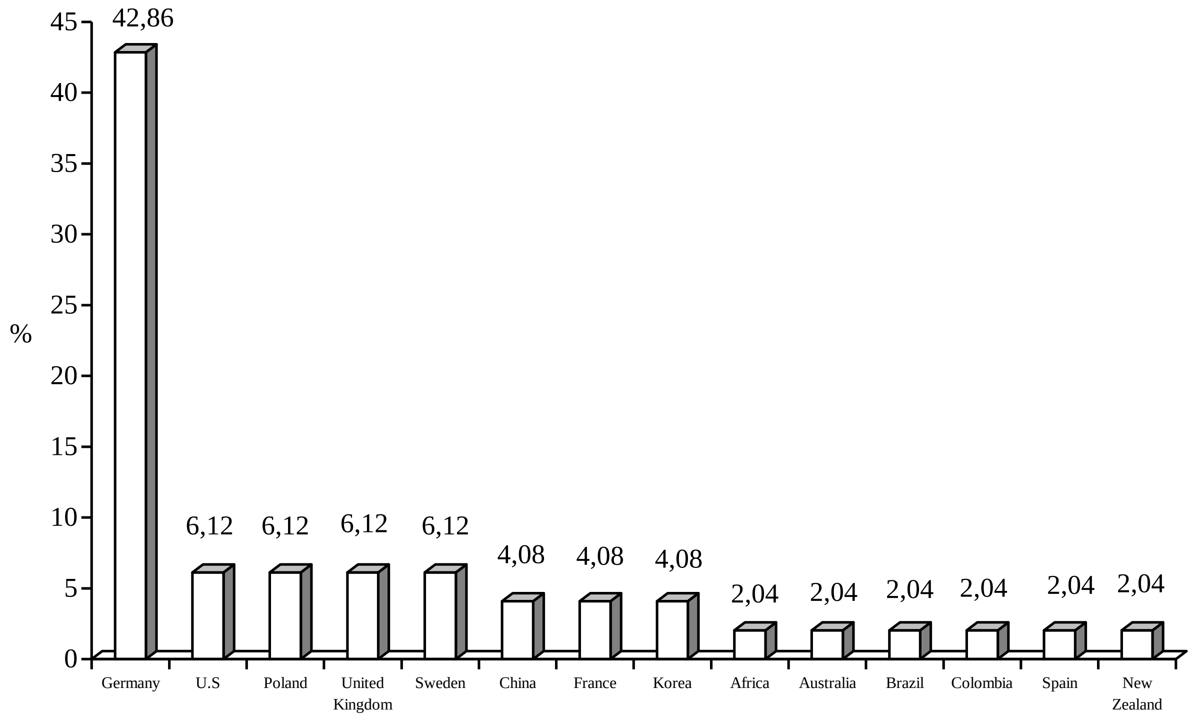

Figure 5. Countries of origin of the researchers under discussion.

It is noteworthy that, as the country that created the concept of Industry 4.0, Germany stood out. The country has the highest representation of theoretical and applied articles, which analyze and discuss problems related to human work in this new industrial approach, as well as other issues related to Industry 4.0.

In emerging countries, such as Brazil, there are still many issues related to the implications of Industry 4.0. In practice, these countries present greater challenges to meet the necessary requirements, one of which is the qualification of people for work in industries.

Qualification of people is the process used in the development of competencies, through training and other practices (Graßmann, 2005). However, the qualification becomes complex in Industry 4.0 since, in order to qualify people, knowing how to measure the necessary human competencies is key.

Studies by Spath et al. (2013) and Becker and Stern (2016), discuss human work perspectives in Industry 4.0, with greater emphasis on the production department, namely: the permanence of people in productive processes as central elements, but with new skills, and the structuring of new tasks.

Competencies for Industry 4.0 in the industry manufacturing

In industries featuring the Industry 4.0 design, new tasks will be created, as well as others will be perfected (Dombrowski; Wagner, 2014; Gorecky et al., 2014; Becker; Stern, 2016). New tasks will be created, since the current production tasks, characterized as easy, repetitive and stressful, will be automated and executed by intelligent systems (Gebhardt; Grimm; Neugebauer, 2015; Becker; Stern, 2016; Vysocky; Novak, 2016).

According to Jasiulewicz-Kaczmarek, Sanik, and Nowicki (2017), the integration between the Internet and production machines, intelligent sensors, and autonomous systems, will increase the complexity of human tasks.

The control of intelligent systems and processes will be the paramount human task in Industry 4.0 (Rüßmann et al., 2015; Marsh; Eyers, 2016). The monitoring of network devices and services, integrated into the production systems, will also intensify in the industries (Gebhardt; Grimm; Neugebauer, 2015; Stock; Seliger, 2016; Ding; Lin, 2017; Jasiulewicz-Kaczmarek; Sanik; Nowicki, 2017; Lalanda; Morand; Chollet, 2017).

Due to the insertion of intelligent processes in the industries, it will be operator's job to monitor and supervise the production systems, with the aid of specific software and technologies (Wittenberg, 2016; Lalanda; Morand; Chollet, 2017; Pacaux-Lemoine et al., 2017).

In addition to the monitoring tasks, human participation in Industry 4.0 will also encompass decision-making processes. The worker will play the role of creative problem solver when faced with complex and dynamic problems (Gorecky et al., 2014; Stock; Seliger, 2016).

In their study, Pfeiffer et al. (2016) cite the main groups of people involved in the context of Industry 4.0: Software developers; Developers of system components; Project manager; System tester; Maintenance and machine operators; Programmers of robotic and computational systems, and; Process supervisors.

In the industry of the future, although the integration of automation and digitization of concurrent processes occurs, people will continue to play a key role in the work (Spath et al., 2013; Becker; Stern, 2016; Pfeiffer, 2016; Vysocky; Novak, 2016; Peruzzini; Pellicciari, 2017). However, it will probably result in a significant impact on the loss of workers' jobs (Sackey; Bester, 2016) and processes of redistribution of human capital (Singh; Sellappan; Kumaradhas, 2013).

In the midst of changes in production processes and in the industrial setting, changes in people's qualification and skill development will surely arise (Chryssolouris et al., 2013; Gebhardt; Grimm; Neugebauer, 2015; Sackey; Bester, 2016). Competency is a generalized term that involves attitude, knowledge, and skills that a person must have to meet an expectation of performance (Armstrong, 2014), or perform tasks.

For Industry 4.0 some human competencies for work in the manufacturing industry are essential in a multidisciplinary context. The Chart 4 presents the main groups of people involved in the context of Industry 4.0 and some of the key human competencies.

Chart 4. Main Professions and basic competencies for Industry 4.0 in the manufacturing industry.

Profession	Competence	Authors
1. Strategic Manager 2. Project Manager	Environmental responsibility	- Marope, Griffin and Gallagher (2017)
	Perspectives and future vision	- Do, Yeh and Madsen (2016)
	Ability to track changes globally	- Gebhardt, Grimm and Neugebauer (2015)
	Entrepreneurial thought	- Grzybowska and Łupicka (2017)
	Creativity	- Gorecky et al. (2014) - Jäger et al. (2015) - Hecklau et al. (2016) - Romero et al. (2016) - Stock and Seliger (2016) - Grzybowska and Łupicka (2017)
	Innovation	- Lee, Kao and Yang (2014) - Joerres et al. (2016) - Romero et al. (2016)
	Communication at a global level	- Becker and Stern (2016) - Hecklau et al. (2016)
	Leadership	- Marope, Griffin and Gallagher (2017)
	Ease of conflit resolution Quick responses to organizations problems	- Grzybowska e Łupicka (2017)
	Critical thinking	- Marope, Griffin and Gallagher (2017)
	Analytical skill	- Grzybowska and Łupicka (2017)
	Knowledge	- Marope, Griffin and Gallagher (2017)
3. Technology Developer	Creativity	- Gorecky et al. (2014) - Jäger et al. (2015) - Hecklau et al. (2016) - Romero et al. (2016) - Stock and Seliger (2016) - Grzybowska and Łupicka (2017)
	Innovation	- Lee, Kao and Yang (2014) - Joerres et al. (2016) - Romero et al. (2016)

To be continued.

Chart 4. Main Professions and basic competencies for Industry 4.0 in the manufacturing industry.

Profession	Competence	Authors
3. Technology Developer	Curiosity	- Marope, Griffin and Gallagher (2017)
	Self-direction and attitude	
	Communication at a global level	- Becker and Stern (2016) - Hecklau et al. (2016)
	In-depth knowledge of digital resouces, technologies and various processes (Big Data, Clound computing, among others).	- Gebhardt, Grimm and Neugebauer (2015)
	In-depth knowledge of Information Technology (IT)	- Gebhardt, Grimm and Neugebauer (2015) - Rüßmann et al. (2015) - Hecklau et al. (2016)
	knowledge of industrial automation	- Hecklau et al. (2016)
	Analytical and graphic skills	- Bermúdez and Juárez (2017)
4. Developer of electronic components 5. Software Developer	Creativity	- Gorecky et al. (2014) - Jäger et al. (2015) - Hecklau et al. (2016) - Romero et al. (2016) - Stock and Seliger (2016)
	Technological innovation	- Joerres et al. (2016) - Romero et al. (2016)
	Communication at a global level	- Becker and Stern (2016) - Hecklau et al. (2016)
	Knowledge of digital resouces, technologies and various processes	Bermúdez and Juárez (2017)
	Knowledge of IT	- Gebhardt, Grimm and Neugebauer (2015) - Rüßmann et al. (2015) - Hecklau et al. (2016)
	Analytical and graphic skills	Bermúdez and Juárez (2017)
6. System Programmer 7. System Tester	Effective communication	- Becker and Stern (2016) - Hecklau et al. (2016)
	Knowledge of digital resouces, technologies and various processes	- Bermúdez and Juárez (2017)
	Knowledge of IT and systems and maintenances	- Gebhardt, Grimm and Neugebauer (2015) - Rüßmann et al. (2015) - Hecklau et al. (2016)

Continuing.

Chart 4. Main Professions and basic competencies for Industry 4.0 in the manufacturing industry.

Profession	Competence	Authors
8. Maintenance Manager	Detailed knowledge of technological components and technologies	- Gebhardt, Grimm and Neugebauer (2015)
9. Process Supervisor	Effective communication	- Becker and Stern (2016) - Hecklau et al. (2016)
	Ability to transfer knowledge	
	Ability to manage teams	- Hecklau et al. (2016)
	Careful observation of the processes in relation to control and failure analysis	- Wittenberg (2016)
	Sensitivity to predict problems	- Jäger et al. (2015) - Joerres et al. (2016)
	Problem-solving ability	- Gorecky et al. (2014) - Hecklau et al. (2016) - Stock and Seliger (2016)
	Management skills	- Spath et al. (2013) - Becker and Stern (2016) - Joerres et al. (2016) - Romero et al. (2016)
	Analytical skills	
10. Machine Manager	knowledge of IT	- Gebhardt, Grimm and Neugebauer (2015) - Rüßmann et al. (2015) - Hecklau et al. (2016)
	Adaptability to changes	- Marope, Griffin and Gallagher (2017)
	Facilidade para resolução de conflitos	- Grzybowska and Łupicka (2017)
	Knowledge of digital technologies	- Hecklau et al. (2016)
	Ease to make decisions	

Conclusion.

In order to achieve the competencies explored in this study, the qualification of people thought interdisciplinary professional training is needed (Gorecky et al., 2014; Pfeiffer, 2016) and integrated training in technical laboratories (Thom et al., 2018) and uses of continuous learning models (Bedolla; D' Antonio; Chiabert, 2017).

It is important that each professional presents a set of specific skills. However, an essential requirement for Industry 4.0 is the IT knowledge and characteristics and particularities of intelligent systems and technologies. It was observed a basic and essential need of the contextualization of Industry 4.0 concepts and application.

Technology Transfer in the Industry 4.0 Scenario

In Germany, the project that propelled Industry 4.0 united the country's universities, industries, and government, mainly focusing on global competitiveness (Cni, 2017). In TT research, the university-industry-government relationship is much discussed, mainly in already consolidated scenarios. In face of this new industrial scenario, this relationship needs to be contextualized, due to numerous changes in the productive and organizational systems.

As the forerunner of the term Industry 4.0, Germany has been leading changes in the industry in recent years (Lee; Kao; Yang, 2014). These changes are also intensifying in the European and Asian countries, and in the United States (Rüßmann et al., 2015). Emerging countries, such as Brazil, face major challenges and much is still in the process of discussion, except for MNCs located in the country. This process of TT in Industry 4.0 will mobilize the entire country, and will demand the effective university-industry-government integration with high-technology manufacturers.

In a simplified way, focusing on the qualification of human capital in the Industry 4.0 Scenario, the government will have to provide research incentives to universities and qualification training centers, participate in policy-making in conjunction with universities and industries, and invest in educational infrastructure in the country. According to the *Conselho Nacional de Indústrias* - Cni (2017), a driving step for the Industry 4.0 Scenario is to modify the educational structure, investing and improving the quality of teaching, especially in the strategic areas. Emerging countries, in practice, have limitations in education and teaching, and thus they face greater difficulties in qualifying people.

The universities of higher education must propose new courses of specialization directed at the training of people for work.

Students, researchers, and professionals from public and private teaching, research, and extension institutions, should unite to rethink the necessary guidelines for human capital. According to Sackey and Bester (2016), Industry 4.0 will require a restructuring of curricula and the development of new disciplines in Teaching Institutions. Practices such as adapting curricula, creating university programs and conducting training sessions are important in the development of human skills in Industry 4.0 (Rüßmann et al., 2015).

The restructuring of curricula can be initiated based in the identification and prioritization of human competences. The manufacturing industries will have to hire skilled workers and/or prepare them so that technologies are efficiently shared and adopted.

Conclusion

The purpose of this study was to address the main human skills required for work in Industry 4.0, and to encourage the development of studies on technology transfer oriented towards Industry 4.0.

It was found that the macro analysis of human skills and competencies for Industry 4.0 is an initial and essential step for TT to take place between the University, Industry and Government spheres.

Qualifying people for work is one of the primary requirements and can be considered a challenge for industries, research institutions, and governments, who must unite in favor of better policies and practices. Thus, the analysis of real changes and prospects of human work is essential for the qualification of people in the Industry 4.0.

The present study is relevant because: i) it may help industries to meet the objectives of Industry 4.0, especially in emerging countries such as Brazil, where much is still being discussed; ii) it contributes to educational institutions, society, and industries in the various sectors, mainly, join forces in the qualification of human capital in the scenario of Industry 4.0 and possibly in the generation of jobs, income, and other advantages; iii) it may provide subsidies for other studies, aimed at identifying, improving or applying practices for the qualification of people in industries that are configured as Industry 4.0.

Depending on the industrial sector, certain human competencies and tasks may stand out from others, due to the divergence of processes in the automotive, food and other sectors. However, for Industry 4.0 (a new industrial configuration approach) the macro analysis of competencies is a relevant scientific contribution, because it enables the creation of branches of competencies, as well as improves the qualification of people according to the reality in question.

References

Albers, A.; Gladysz, B.; Pinner, T.; Butenko, V.; Stürmlinger, T. (2016). Procedure for Defining the System of Objectives in the Initial Phase of an Industry 4.0 Project Focusing on Intelligent Quality Control Systems. *Procedia CIRP*, 52, 262-267.

Anderl, I. R. Industrie 4.0 (2014). Advanced Engineering of Smart Products and Smart Production. In*: Anais* do XIX Internation Seminar on High Technology. Piracicaba, SP.

Annunziata, M.; Biller, S. (2017). *The Future of Work Starts Now*. Access in September 3, 2017, http://www.ge.com.

Armstrong, M. (2014). *Handbook of human resource management practice*. 13. London: Kogan Page.

Becker, T.; Stern, H. (2016). Future Trends in Human Work area Design for Cyber-Physical Production Systems. *Procedia CIRP*, 57, 404-409.

Bedolla, J. S.; D' Antonio, G.; Chiabert, P. (2017). A novel approach for teaching IT tools within Learning Factories. *Procedia Manufacturing*, 9, 175-181.

Bermúdez, M. D.; Juárez, B. F. (2017). Competencies to adopt Industry 4.0 for operations management personnel at automotive parts suppliers in Nuevo Leon. In*: Anais* of the Proceedings of the International Conference on Industrial Engineering and Operations Management, Bogota, Colombia.

Chryssolouris, G.; Mavrikios, D.; Mourtzis, D. (2013). Manufacturing Systems: Skills & Competencies for the Future. *Procedia CIRP*, 7, 17-24.

Cni - *Conselho Nacional de Indústria*. (2017). *New Industrial Era Will Transform Global Productivity*. Access in September 2, 2017, http://www.portaldaindustria.com.br.

Davenport, J. (2013). Technology Transfer, Knowledge Transfer and Knowledge Exchange in the Historical Context of Innovation Theory and Practice. In: *Anais* of the knowledge Exchange, an Interactive Conference. Lancaster University.

Ding, I. J.; Lin, S. K. (2017). Performance Improvement of Kinect Software Development Kit-Constructed Speech Recognition Using a Client-Server Sensor Fusion Strategy for Smart Human-Computer Interface Control Applications. *IEEE Access*, 5, 4154-4162.

Do, B. R.; Yeh, P. W.; Madsen, J. (2016). Exploring the relationship among human resource flexibility, organizational innovation and adaptability culture. *Chinese Management Studies*, 10(4), 657-674.

Dombrowski, U.; Wagner, T. (2014). Mental Strain as Field of Action in the 4th Industrial Revolution. *Procedia CIRP*, 17, 100-105.

Drath, R.; Horch, A. (2014). Industrie 4.0: Hit or Hype? *IEEE industrial electronics magazine*, 56-58.

Etzkowitz, H.; Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ‘‘Mode 2’’ to a Triple Helix of university–industry–government relations. *Research Policy*, 29, 109-123.

Gebhardt, J.; Grimm, A.; Neugebauer, L. M. (2015). Developments 4.0 Prospects on future requirements and impacts on work and vocational education. *Journal of Technical Education*, 117-133.

Gebo Cermex. (2017). *Industry 4.0 driven by simulation*. Access in September 5, 2017, http://www.gebocermex.com.

Gil, A. C. (2008). *How to design research projects*. São Paulo: Atlas.

Gorecky, D.; Khamis, M.; Mura, K. (2015). Introduction and establishment of virtual training in the factory of the future*. International Journal of Computer Integrated Manufacturing*, 30(1), 182-190.

Graßmann, H. (2005). *Qualifikation, Kompetenz und Personalentwicklung – Zum Einfluss von Informations- und Kommunikationstechnik auf Bankmitarbeiter*. Mering: Rainer Hampp Verlag.

Grzybowska, K.; Łupicka, A. (2017). Key competencies for Industry 4.0*. Economics & Management Innovations*, 1(1), 250-253.

Haddara, M.; Elragal, A. (2015). The Readiness of ERP Systems for the Factory of the Future. *Procedia Computer Science*, 64, 721-728.

Hameri, A. P. (1996). Technology transfer between basic research and industry. *Technovation*, 16(2), 51-57.

Hecklau, F.; Galeitzke, M.; Flachs, S.; Kohl, H. (2016). Holistic Approach for Human Resource Management in Industry 4.0. *Procedia CIRP*, 54, 1-6.

Hofmann, E.; Rüsch, M. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry*, 89, 23-34.

Jäger, A.; Sihn, W.; Ranz, F.; Hummel, V. (2015). *Implications for Learning Factories from Industry 4.0 Challenges for the human factor in future production scenarios*. Access in September 7, 2017, https://www.kth.se/polopoly.

Jasiulewicz-Kaczmarek, M.; Saniuk, A.; Nowicki, T. (2017). The Maintenance Management in the Macro-Ergonomics Context. *Advances in Intelligent Systems and Computing*, 487, 35-46.

Joerres, J. et al. (2016). *The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*. Global Challenge Insight Report: 167 p.

Kumar, V.; Kumar, U.; Persaud, A. (1999). Building Technological Capability through Importing Technology: The Case of Indonesian Manufacturing Industry. *The Journal of Technology Transfer*, 24, 81-96.

Lalanda, P.; Morand, D.; Chollet, S. (2017). Autonomic Mediation Middleware for Smart Manufacturing. *IEEE Internet Computing*, 21(1), 32-39.

Lee, E. A. (2008). Cyber Physical Systems: Design Challenges. In: Anais do IEEE International Symposium. Orlando, USA.

Lee, J.; Kao, H. A.; Yang, S. (2014). Service innovation and smart analytics for Industry 4.0 and big data environment. *Procedia CIRP*, 16, 3-8.

Marope, M.; Griffin, P.; Gallagher, C. (2017). *Future Competences and the Future of Curriculum: A Global Reference for Curricula Transformation*. Paris: International Bureau of Education.

Marsh, J. L.; Eyers, D. (2016). Increasing Production Efficiency Through Electronic Batch Record Systems: A Case Study. *Smart Innovation, Systems and Technologies*, 52, 261-269.

Pacaux-Lemoine, M. P.; Trentesaux, D.; Rey, G. Z.; Millot, P. (2017). Designing intelligent manufacturing systems through Human-Machine Cooperation principles: A human-centered approach. *Computers & Industrial Engineering*, 1-28.

Pagani, R. N.; Kovaleski, J. L.; Resende, L. M. (2015). Methodi ordinatio®: a proposed methodology to select and rank relevant scientific papers encompassing the impact factor, number of citation, and year of publication. *Scientometrics*, Springer, 105(3), 2109-2135.

Pagani, R. N.; Zammar, G.; Kovaleski, J. L.; Resende, L. M. (2016). Technology Transfer Models: Typology and a Generic Model. *International Journal of Technology Transfer and Commercialisation*, 14, 20-41.

Park, S. H.; Shin, W. S.; Park, Y. H.; Lee, Y. (2017). Building a new culture for quality management in the era of the Fourth Industrial Revolution. *Total Quality Management & Business Excellence*, 28(9), 934-945.

Park, S.; Lee, S. (2017). A study on worker's positional management and security reinforcement scheme in smart factory using industry 4.0-based bluetooth beacons. *Lecture Notes in Electrical Engineering*, 421, 1059-1066.

Peruzzini, M.; Pellicciari, M. (2017). A framework to design a human-centred adaptive manufacturing system for aging workers. *Advanced Engineering Informatics*, 1-20.

Pfeiffer, S. (2016). Robots, Industry 4.0 and Humans, or Why Assembly Work Is More than Routine Work. *Societies*, 6(2), 2-26.

Pfeiffer, T.; Hellmers, J.; Schön, E. M.; Thomaschewski, J. (2016). Empowering User Interfaces for Industrie 4.0. *Proceedings of the IEEE*, 104(5), 986-996.

Porter, M. E.; Heppelmann, J. E. (2014). How Smart, Connected Products Are Transforming Competition. *Harvard Business Review*.

Rodič, B. (2017). Industry 4.0 and the New Simulation Modelling Paradigm. *Oganizacija*, 50(3), 193-207.

Romero, D.; Bernus, P.; Noran, O.; Stahre, J.; Berglund, A. F. (2016). The operator 4.0: Human cyber-physical systems & adaptive automation towards human-automation symbiosis work systems. *IFIP Advances in Information and Communication Technology*, 488, 677-686.

Rüßmann, M.; Lorenz, M.; Gerbert, P.; Waldner, M.; Justus, J.; Engel, P.; Harnisch, M. (2015). *Industry 4.0 The Future of Productivity and Growth in Manufacturing Industries*. The Boston Consulting Group.

Saad, M.; Zawdie, G. (2005). From Technology Transfer to the Emergence of a Triple Helix Culture: The Experience of Algeria in Innovation and Technological Capability Development. *Technology Analysis & Strategic Management*, 17(1), 89-103.

Sackey, S. M.; Bester, A. Industrial engineering curriculum in industry 4.0 in a South African context. (2016). *South African Journal of Industrial Engineering*, 27(4), 101-114.

Seaton, R. A. F.; Cordey-Hayes, M. (1993). The development and application of interactive models of industrial technology transfer. *Technovation*, 13, 45-53.

Silva, E. L.; Menezes, E. M. (2005). *Methodology of the research and elaboration of dissertation*. Florianópolis: Ufsc.

Silva, V. L.; Kovaleski, J. L.; Pagani, R. N. (2018). Technology transfer in the supply chain oriented to industry 4.0: a literature review. *Technology Analysis & Strategic Management*, Doi: 10.1080/09537325.2018.1524135.

Singh, B.; Sellappan, N.; Kumaradhas, P. (2013). Evolution of Industrial Robots and their Applications. *International Journal of Emerging Technology and Advanced Engineering*, (3), 763-768.

Spath, D.; Ganschar, O.; Gerlach, S.; Hämmerle, M.; Krause, T.; Schlund, S. (2013). Produktionsarbeit der Zukunft: Industrie 4.0. *Fraunhofer IAO*, 1-150.

Stock, T.; Seliger, G. (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP*, 40, 536-541.

Takahashi, V. P. (2005). Transfer of technological knowledge: a multiple case study in the pharmaceutical industry. *Gestão & Produção*, 12(2), 255-269.

Tasevski, J.; Nikolić, M.; Mišković, D. (2013). Integration of an Industrial Robot with the Systems for Image and Voice Recognition. *Serbian Journal of Electrical Engineering*, 10(1), 219-230.

Thom, W.; Stefan, L.; Kreimeier, D.; Kuhlenkötter, B. (2018). Evolution of SMEs towards Industrie 4.0 through a scenario based learning factory training. *Procedia Manufacturing*, 23, 141-146.

Ullah, M. I.; Ajwad, S. A.; Irfan, M.; Iqbal, J. (2016). Non-linear Control Law for Articulated Serial. *Elektronika ir Elektrotechnika*, 22(1), 1, 1-5.

Vysocky, A.; Novak, P. (2016). Human - Robot collaboration in industry*. MM Science Journal*, 903-906.

Wang, W.; Zhu, X.; Wang, L.; Qiu, Q.; Cao, Q. (2016). Ubiquitous robotic technology for smart manufacturing system. *Computational Intelligence and Neuroscience*.

Witkowski, K. (2017). Internet of Things, Big Data, Industry 4.0: Innovative Solutions in Logistics and Supply Chains Management. *Procedia Engineering*, 182, 763-769.

Wittenberg, C. (2016). Human-CPS Interaction - requirements and human-machine interaction methods for the Industry 4.0, *IFAC-PapersOnLine*, 49(19), 420-425.