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ENDÜSTRİ 4.0'IN GEREKLİLİĞİ, AVANTAJ VE DEZAVANTAJLARI: TÜRK LİSANSÜSTÜ ÖĞRENCİLERİNİN ALGILARI ÜZERİNE BİR ARAŞTIRMA

THE NECESSITY, ADVANTAGES AND DISADVANTAGES OF INDUSTRY 4.0: A STUDY OF TURKISH GRADUATE STUDENTS' PERCEPTIONS

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Öz: Endüstri 4.0 olarak bilinen dördüncü sanayi devrimi, imalat sanayinde ortaya çıkmıştır ve esas olarak otomasyon ve veri değişimine dayalıdır. Büyük bir yenilik gibi göründüğü için devrim olarak adlandırılır ve bu nedenle bu alandaki makaleler Endüstri 4.0'ın yenilik boyutuyla alakalıdır. Literatürden hareketle, Endüstri 4.0'ın toplum ve işgücü üzerindeki etkisinin göz ardı edildiği söylenebilir. Literatürdeki boşluğu doldurmak için bu çalışma, toplumun mevcut veya gelecekteki işgücünü oluşturan lisansüstü öğrencilerin algılarından hareketle Endüstri 4.0'ın gerekliliğini, avantajlarını ve dezavantajlarını analiz etmeyi amaçlamaktadır. Bu amacı gerçekleştirmek için öncelikle Endüstri 4.0'ın gerekliliği, avantajları ve dezavantajları ile ilgili literatür taranmıştır. Sonrasında 202 lisansüstü öğrencisine online anket uygulanmış ve öğrencilerin Endüstri 4.0 konusundaki bilgi düzeyleri ile Endüstri 4.0'ın gerekliliğine yönelik algıları arasındaki ilişkinin varlığını belirlemek üzere korelasyon analizi gerçekleştirilmiştir. Araştırmanın sonuçları, örneklemde yer alan öğrencilerin Endüstri 4.0'ın son derece gerekli olduğuna inandıklarını göstermektedir. Bu çalışmanın bir başka ilginç sonucu da öğrencilerin Endüstri 4.0 konusundaki bilgi düzeylerinin öğrenim gördükleri enstitüye göre farklılık göstermemesine rağmen Endüstri 4.0'ın gerekliliğine olan inançlarının farklı çıkmasıdır. Son olarak, Endüstri 4.0'ın en önemli dezavantajı olarak "yüksek ilk yatırım maliyetleri" öne çıkarken, Endüstri 4.0'ın en önemli avantajını "verimlilik artışı" temsil etmektedir. Endüstri 4.0'ın toplum ve bireyler üzerindeki, mevcut ve potansiyel teknolojik ve ekonomik yönleriyle ilgili çalışmalar olmasına rağmen, bunun sosyal etkisini anlamak konusunda bir eksiklik söz konusudur. Bu boşluğu doldurmak için bu çalışma, lisansüstü öğrencilerin algılarını sorgulayarak ve Endüstri 4.0'ın avantaj ve dezavantajlarını da inceleyerek Endüstri 4.0'ın toplum ve bireyler üzerindeki teknolojik, ekonomik ve sosyal etkilerine bütüncül bir yaklaşımla odaklanmaya çalışmaktadır.

Anahtar Kelimeler: Lisansüstü Öğrenciler, Endüstri Devrimi, Endüstri 4.0, Endüstri 4.0'ın Gerekliliği, Endüstri 4.0'ın Avantajları, Endüstri 4.0'ın Dezavantajları

Abstract: Fourth industrial revolution, known as Industry 4.0 arose in manufacturing industry and it mainly based on automation and data exchange. It is called as a revolution since it seems like a big innovation and therefore the articles in this area are relevant to its innovation dimension. Based upon the literature it can be said its impact on the society and on the workforce has been ignored. To fill the gap in the literature, this study aims to analyse the necessity, advantages and disadvantages of Industry 4.0 based on the perceptions of graduate students who constitute the existing or future workforce of the society. To accomplish this aim, first the literature about the necessity, advantages, and disadvantages of Industry 4.0 was reviewed. Then an online survey was conducted with 202 graduate students and a correlation analysis was run to identify the existence of relationship between students' knowledge level in Industry 4.0 and beliefs towards necessity of Industry 4.0. Results of the study indicate that sampled students believe that Industry 4.0 is highly necessary. Another interesting result of this study is that the knowledge level in Industry 4.0 of students does not differ according to the institute where they study, but their belief towards necessity of Industry 4.0 differs. Finally, "increased productivity" represents the most important advantage of Industry 4.0 whereas "high initial investment costs" stands out as the most important disadvantage of Industry 4.0. Although there have been studies regarding to existing and potential technological and economical aspects on society and individuals, there is a lack of understanding of the social impact of it. To fill this gap, this study attempts to focus on the technological, economical, and social impacts of Industry 4.0 on society and individuals with a holistic

approach by questioning the perceptions of university students and examining the advantages and disadvantages of Industry 4.0 as well.

Key Words: Graduate Students, Industrial Revolution, Industry 4.0, Necessity for Industry 4.0, Advantages of Industry 4.0, Disadvantages of Industry 4.0

1. Introduction

Today's society has been experiencing an innovation process that reflects technological developments in every field (Mariani and Borghi, 2019). Industry has evolved over the centuries and gave birth to Industry 4.0 to meet today's needs. The concept was introduced with the Hannover Fair Event in 2011 as part of the German economy development plans, and the fair also symbolized as the beginning of Industry 4.0 (Qin et al., 2016).

According to Kuhn, scientific revolutions occur because of the loss of functionality of the existing order (Kuhn, 2012). In recent years, factors such as international competition, market instability, increasing interest in personalized products, shortening of product life have necessitated high quality, low cost and in a short time required to meet the demands in the manufacturing industry (Hofmann and Rüsch, 2017; Mrugalska and Wyrwicka, 2017). To meet these demands, some technological and innovative developments have been integrated into the existing order. Thus, Industry 4.0 enables the integration of complex physical machines and devices with network sensors and software to achieve more comprehensive business and even social results (Lu, 2017).

Industry 4.0 represents current technological trends (Sony, 2018), and it changes both the industries and social and economic life (Reischauer, 2018). The literature on Industry 4.0 mainly focuses on the innovation aspects of the concept. For this reason, the impact of these sudden technological developments and digitalization on society and individuals creates a new field of research. Therefore, to overcome the deficiency in the research field, technological developments should also take its share from the social paradigm (Morrar et al., 2017; Skobelev and Borovik, 2017).

Investments in any new technology are costly and require a lot of time and effort, and future professionals can influence the success of these ventures (Al-Emran et al., 2018). It is necessary to have the ability to train qualified graduates with the skills required by Industry 4.0, and to explore the gap between the expectation of Industry 4.0 and the ability of the current student (Pattanapairoj et al., 2021). The importance of this research is that it focuses on how individuals and society can fully benefit from Industry 4.0 and considers the concept from the perspective of students. Hence, it is necessary to determine the perceptions of the students about industry 4.0 who will be active labour force and to integrate the council into the society.

In this study, we are seeking an answer to the question of what the perception of postgraduate students about industry is 4.0, who already have a place in

business dynamics as a labour force. We will present the industry 4.0 awareness of graduate students at both social sciences institute and science and engineering institute.

The rest of the article is organized as follows. Section 2 gives a brief review literature review of Industry 4.0. Section 3 presents the methodology of the study. Finally, in Section 4, the results are discussed, and it is followed by our conclusion.

2. Components of Industry 4.0

Since the current approaches of value creation cannot meet the requirements demanded by today's industry, starting from cost efficiency, and extending to sustainability, the concept of industry 4.0 has been proposed (Hofmann and Rüsch, 2017). The concept of Industry 4.0 refers to the components that make up a whole, rather than a definition (Lasi et al., 2014). The innovative technologies discussed in this research are as follows:

Additive Manufacturing - 3D Printers: Additive Manufacturing is a series of processes that accumulate material in layers to produce 3D material and shorten the time to produce completely dense parts (Anand et al., 2018).

Internet of Things: The IoT (Internet of Things) is the use of objects or sensors that can connect the digital world and the real world for agile management of complex systems (Caron et al., 2016).

Smart Factories: Smart factories are a new kind of factories that transform central control into decentralized intelligence by making physical objects and people an integrated part of the production process with innovative technologies such as IoT, CPS, etc. (Shrouf et al., 2014). With Industry 4.0, factories become more flexible, more dynamic, smarter, as well as self-optimizing and automating (Lu, 2017).

Cyber Physical Systems - Cyber Security: CPS are systems where calculations are integrated with physical processes (Lee, 2008). It enables the realization of innovative functions of physical objects over networks (Lu, 2017). In short, they are industrial automation systems that combine the physical and virtual world and develop innovative forms of operation (Hofmann and Rüsch, 2017).

Big Data: Management and distribution of complex data is critical to the self-learning machines offered by Industry 4.0 (Lee et al., 2014). Processed or unprocessed data will become more accessible during the production process. The datasets formed by these various data can be used for monitoring, control and optimization in order to improve process and product quality (Reis and Gins, 2017).

Autonomous Robots: These are the smart machines that are part of a distributed production line that requires mobile support to shorten production time or make ready them to another machine for further processing (Gonzalez et al., 2017).

Simulation: Production processes and performances are easily simulated by integrating different computer programs to optimize all industrial processes (Karaman Akgül et al., 2018).

System Integration: Advances in technology exacerbate competition in the market and lack of control or waste is unacceptable. Manufacturers can only meet the demands of the market in the shortest time and in the best way with systems where each process is integrated with each other (Doh et al., 2016).

Cloud Technologies: The production context accelerates production processes with different cloud technologies and provides virtual access to assets. Thus, market demands can be better met. Cloud technologies have become the foundation of innovative information technologies (Pedone and Mezgar, 2018).

Augmented Reality: AR integrates virtual information into the real environment and thus allows the virtual reality to be perceived as present in the conditions of the moment. Advanced portable technology supports the feasibility of augmented reality, eliminating time and space constraints (Newcombe et al., 2011).

Machine to Machine (M2M): Machine-to-machine access is becoming more and more popular with the Internet of objects. M2m allows for increased production and access over the network (Tagarian and Ghahfarokhi, 2019).

3. Materials and Methods

In this research a survey was conducted with postgraduate students studying at Yildiz Technical University (İstanbul, Turkey). A detailed questionnaire was prepared after literature review to gather data. The questionnaire was prepared by compiling based upon a detailed literature review (Mrugalska and Wyrwicka, 2017; Lu, 2017; Thames and Schaefer, 2017; Kiel et al., 2017; Schumacher et al., 2016; Rüßmann et al., 2015). The statements in the questionnaire aim to reveal the level of knowledge in Industry 4.0, beliefs towards the necessity of Industry 4.0, and students' opinions on the advantages and disadvantages of Industry 4.0.

The questionnaire consisted of five main parts. In this first part, students' demographic information was included. The second part included students' knowledge level in Industry 4.0 and beliefs towards necessity of Industry 4.0. The other parts compromised of knowledge levels in Industry 4.0 technologies, advantages of Industry 4.0 and disadvantages on Industry 4.0 respectively. Except from the first part, five-point Likert scale was used.

An online questionnaire was prepared and sent to the students studying at Institute of Social Sciences and Institute of Science and Engineering of Yildiz Technical University via e-mail. All the master and Ph.D. students were invited to participate in the survey and the volunteer students were included in the sample. Thus, the sampling method was voluntary response sampling. A total of 229

student volunteered for the survey. A data cleaning proses was run and finally 202 students were included in the analysis.

This is a descriptive study. In the data analysis stage, Descriptive and frequency analysis, Spearman's correlation analysis and Mann-Whitney U analysis were conducted. Descriptive analysis and frequency analysis were conducted to describe the perception of graduate students on the necessity, advantages, and disadvantages of industry 4.0. Spearman's correlation analysis was applied to define the relationship between knowledge level in Industry 4.0 and belief towards necessity of Industry 4.0. Besides, Mann-Whitney U analysis were conducted to identify the differences in perceptions of the students based on their characteristics. in data analysis section.

4. Results and Discussion

The data was gathered from 202 graduate students. The sample consists of 145 (71.8%) master students and 57 (28.2%) Ph.D. students. 104 (51.5%) of these students are studying at Institute of Social Sciences (Business Administration, Accounting and Finance, HRM etc.) and 98 (48.5%) of them are studying at Institute of Science and Engineering (Mechanical engineering, Computer engineering, Information technologies, Electrical engineering, Industrial Engineering etc.). Besides, 87 (43.1%) of these students have bachelor's degree in social and Humanities Sciences (Business Administration, Economics, International Relations, Phycology, Literature, History etc.) and 115 (56.9%) have bachelor's degree in engineering (Mechanical Eng., Computer Eng., Electrical Eng., Industrial Eng., Environmental Eng., Civil Eng. etc.) (Table 1).

Table 1: Sample descriptive

Descriptive		n	%
Degree	Master	145	71.8
	Ph.D.	57	28.2
Institute	Social Sciences	104	51.5
	Science and Engineering	98	48.5
Bachelor's Degree	Social and Humanities Sciences	87	43.1
	Engineering	115	56.9

The students were asked to define their knowledge level in Industry 4.0 in five-points Likert scale (1 = I have no idea. 5 = I have a very good level of knowledge) and their beliefs towards necessity of Industry 4.0 in five-points liker scale (1 = Not necessary at all. 5 = It is really necessary). Mean values of the answers are given in Table 2.

Table 2: Postgraduate students' knowledge level and belief towards Industry 4.0

	Mean	Standard Deviation	Spearman's rho
Knowledge level in Industry 4.0	3.16	0.91	0.303**
Belief towards necessity of Industry 4.0	4.23	0.67	

** Correlation is significant at the 0,01 level (2-tailed).

As can be seen in Table II, the postgraduate students seem to have a moderate ($\bar{x}$ = 3.16, std. = 0.91) knowledge about Industry 4.0 and they think that Industry 4.0 is a necessary issue ($\bar{x}$ = 4.23, std. = 0.67).

Based on these results, it can be said that graduate students participating in the research believe that Industry 4.0 is highly necessary. Industry 4.0 penetrates both our industrial and social lives. It is obvious that the requirements of this industrial revolution will make changes in every segment of society. Therefore, the massive application of innovative technologies that make up Industry 4.0 requires readiness for changes in society (Feshina et al., 2019). Today's students are digital natives. It is natural for them to have high beliefs in Industry 4.0, which includes integrating high technologies into the industry more than ever. In addition, students who are aware of this need are the key to standing out in the digital age (Selamat, et al., 2017).

Although the belief in the necessity of Industry 4.0 is high, in the sample of students from both social sciences and engineering fields, the level of knowledge is average. Industry 4.0 embodies various and rapid changes by its nature. Therefore, digital transformation requires continuing education. What needs to be done in this regard is to increase the level of knowledge related to the new industrial revolution, primarily on basic concepts, and then to improve on technical issues (Motyl et al., 2017). It should not be forgotten that increasing students' knowledge level is not only limited to individual outputs but also to raise important competencies for the business world (Schuster et al., 2015).

Correlation analysis was run to identify the existence of relationship between students' knowledge level in Industry 4.0 and beliefs towards necessity of Industry 4.0. Before the correlation analysis, we examined the distributions of the mentioned variables to decide whether to use a parametric or a non-parametric test. Kolmogorov-Simirnov and Shapiro-Wilk tests show that none of the variables are normally distributed (all the significance levels were lower than 0,000). After KS and SW tests we checked Q-Q plots and histograms, but there was no sign of normal distribution of the variables. Thus, we used Spearman Correlation which is a non-parametric test. According to the result, the correlation coefficient (Spearman's rho) is 0.303 and it is statistically significant (Table II). Thus, there is a positive correlation between students' knowledge level in Industry 4.0 and their beliefs towards necessity of Industry 4.0.

Studies are discovering an exciting fact that social influence variables have an impact on perceived usefulness and intention to use of Industry 4.0 (Nguyen & Nguyen, 2020). For this reason, exposing students to the effects of industry 4.0 in the classrooms before they replace the complex business world as a workforce can be a useful education method for developing a qualified workforce. It may be a strategic step that training can be supplied to address the integration of technology into the educational process (Castillo-Vergara et al., 2022).

Students' knowledge level in Industry 4.0 and beliefs towards necessity of Industry 4.0 could be affected by their education level and field. To test this possible effect, students' knowledge level and beliefs were compared according to their education level, the institute where they study and their bachelor's degree. Since these variables are not normally distributed, to compare the mean values, suitable non-parametric tests are applied. The students could be divided in two groups for each of the variables according to education level, institute, and their bachelor's degree variables. Thus, Mann-Whitney U test, which is a non-parametric test compares two independent groups, is used to test whether students' knowledge level in Industry 4.0 (KI4.0) and beliefs towards necessity of Industry 4.0 (NI4.0) change according to their education level, the institute and bachelor's degree. The descriptive statistics and Mann-Whitney U tests result are presented in Table 3.

Table 3: Postgraduate students' knowledge level and beliefs towards Industry 4.0 according to education level, institute, and bachelor's degree

Degree				
	Master	Ph.D.	Mann-Whitney U Test	
	Mean	Mean	Stat.	Sig
KI4.0	3.00	3.58	4.066	<0.001
NI4.0	4.18	4.35	1.433	0.152
Institute				
	Social Sciences	Science and Engineering	Mann-Whitney U Test	
	Mean	Mean	Stat.	Sig
KI4.0	3.13	3.19	0.012	0.991
NI4.0	4.13	4.34	2.192	0.028
Bachelor's Degree				
	Social and Humanities Sci.	Engineering	Mann-Whitney U Test	
	Mean	Mean	Stat.	Sig
KI4.0	2.99	3.30	2.052	0.040
NI4.0	4.11	4.31	2.042	0.041

*KI4.0: Knowledge level in Industry 4.0
*NI4.0: Belief towards necessity of Industry 4.0

According to the results of Mann-Whitney U test (Table III) knowledge level in Industry 4.0 of students differs according to their degrees (U= 4.066, sig <0.001), but their beliefs towards necessity of Industry 4.0 do not differ according to their degrees (U= 1.433, sig = 0.152). As we can see in Table III, knowledge level in Industry 4.0 of Ph.D. students ($\bar{x}$ = 3.58) is higher than the knowledge level of

master students ($\bar{x}$ = 3.00). Industry 4.0 practices will threaten occupations requiring special education rather than low-paid and untrained workers. Complex processes that higher education graduates who do high-skilled jobs can do can be easily done by machines (Bonekamp and Sure, 2015). In this framework, graduate and PhD students are depicted in the continuous self-improvement momentum of Industry 4.0 in order not to lose their jobs or the value they create. With the training modules covering both masters and PhD students, solid bridges can be established between innovative technologies and human applications that Industry 4.0 integrates into the business world (Kharchenko et al., 2017).

The results of Mann-Whitney U test (Table III) shows that knowledge level in Industry 4.0 of students does not differ according to the institute where they study (U= 0.012, sig = 0.991), but their beliefs towards necessity of Industry 4.0 differ (U= 2.192, sig = 0.028). The students studying at Institute of Science and Engineering ($\bar{x}$ = 4.34) have higher beliefs towards necessity of Industry 4.0 than the students studying at Institute of Social Science ($\bar{x}$ = 4.13). Considering future job fields and potential jobs, much is expecting from engineering students, such as to meet the requirements of the industrial revolutions and the community's demands for it. Because human work processes in the field of engineering are increasingly transferred to virtual processes. This stimulates engineering students in lifelong learning and self-development (Schuster et al., 2015). For this reason, it is understandable that their beliefs about industry 4.0, which are expected to shape their future, are high. Because it is perceived that industry 4.0 is a bigger threat for engineering students.

According to the results of Mann-Whitney U test (Table III) both the students' knowledge level in Industry 4.0 (U= 2.052, sig = 0.040) and beliefs towards necessity of Industry 4.0 (U= 2.042, sig = 0.041) differ according to their bachelor's degree. Students who have bachelor's degree in Engineering ($\bar{x}$ = 3.30) have a higher knowledge level in Industry 4.0 than the students who have bachelor's degree in Social and Humanities Sciences ($\bar{x}$ = 2.99). Besides, students who have bachelor's degree in Engineering ($\bar{x}$ = 4.31) have a higher belief towards necessity of Industry 4.0 than the students who have bachelor's degree in Social and Humanities Sciences ($\bar{x}$ = 4.11). One possible explanation for these results might be the belief that industry 4.0 is a bigger threat for engineering students. Besides, research in the field of Industry 4.0 shows that Industry 4.0 and its elements can be a great opportunity, which is focused on digital technologies, smart systems and can increase business potential, especially in the manufacturing sectors where the demand for engineering labor is reasonably high (Išoraitė et al., 2022).

In this study, postgraduate students' knowledge levels in Industry 4.0 technologies have been also examined. Total of 11 Industry 4.0 technologies were added in the questionnaire. The students were asked to define their knowledge levels in each of these technologies in a five-point Likert scale (1 = I have no idea,

5 = I have a very good level of knowledge). The mean values of students' knowledge levels in each of the Industry 4.0 technologies are shown on Figure 1.

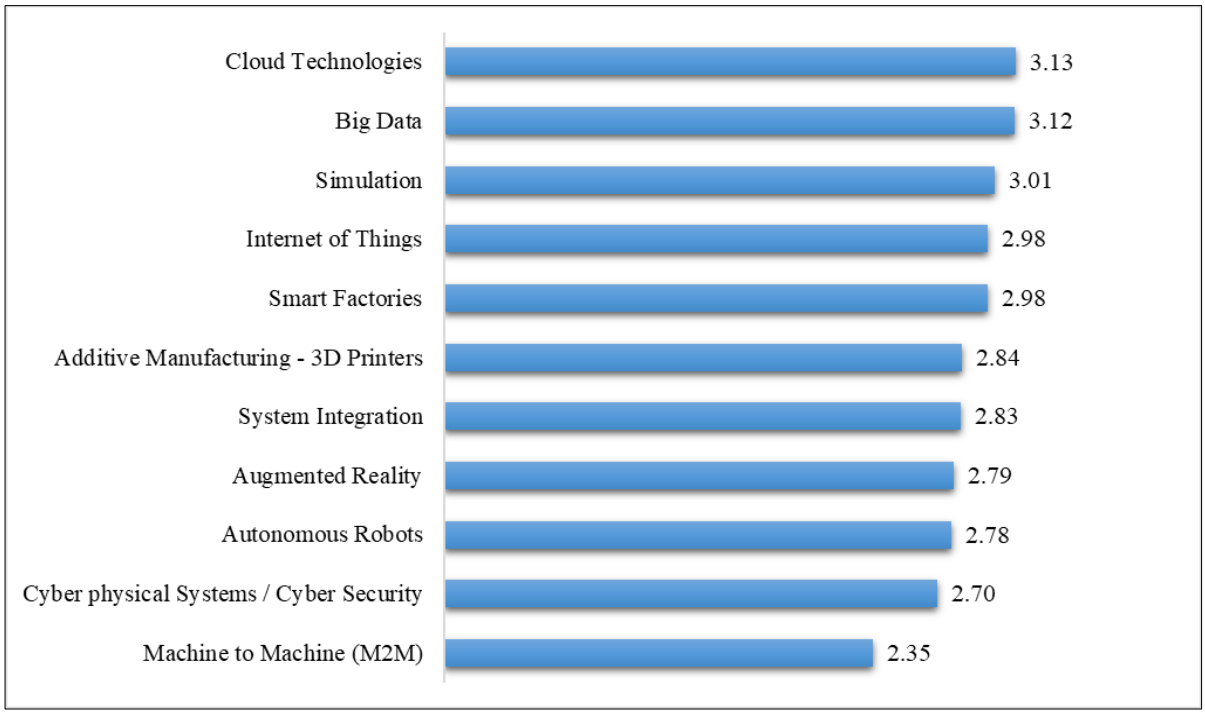

Figure 1: Knowledge Levels in Industry 4.0 Technologies

Modern trends of Industry 4.0 need workers to acquire new skills, knowledge, and competencies (Zhanna and Nataliia, 2020). According to Figure 1, the technologies with the highest knowledge level of students are cloud technologies, big data and simulation, while the technologies with lowest knowledge level are autonomous robots, cyber physical systems/cyber security and machine to machine (M2M). The reason for this may be that one of the most adapted technologies in Industry 4.0's daily life is cloud technology. It is frequently used not only in business life, but also by students.

In addition, big data and simulation have become the concepts we are prepared to encounter in almost every company with providing several opportunities (Chen and Quan-Haase, 2020; Dawson et al., 2007). However, high technologies with the lowest level of knowledge of students represent the part of Industry 4.0 that has not been widely integrated into business life. The fact that physical elements begin to be represented virtually or by non-human elements is a different phase of digitalization (Gökalp et al., 2017). So, the difficulty to access these high technologies currently restricts the knowledge of students.

Mean values of students' knowledge levels in each of the industry 4.0 technologies according to their education level, the institute where they study, and their bachelor's degree are given in Table 4. Mann-Whitney U test is used to test whether students' knowledge level in Industry 4.0 technologies change according to their education level, institute, and bachelor's degree. The significance levels of Mann-Whitney U test statistics are given on the Table 4.

Table 4: Students' knowledge levels in Industry 4.0 technologies

Industry 4.0 technologies	Total	Degree			Institute			Bachelor's Degree		
		Master	Ph.D.	U	SS	SaE	U	SaHS	ENG	U
	$\bar{x}$	$\bar{x}$	$\bar{x}$	Sig	$\bar{x}$	$\bar{x}$	Sig	$\bar{x}$	$\bar{x}$	Sig
Additive Manufacturing 3D Printers	2.84	2.82	2.88	0.633	2.61	3.08	0.001	2.57	3.03	0.001
Internet of Things	2.98	2.90	3.19	0.078	2.70	3.28	<0.001	2.55	3.30	<0.001
Smart Factories	2.98	2.91	3.14	0.177	2.84	3.12	0.047	2.74	3.16	0.006
Cyber physical Systems / Cyber Security	2.70	2.63	2.88	0.165	2.68	2.72	0.962	2.68	2.72	0.867
Big Data	3.12	3.03	3.37	0.035	3.06	3.19	0.532	3.03	3.19	0.363
Autonomous Robots	2.78	2.80	2.74	0.571	2.51	3.07	<0.001	2.48	3.01	<0.001
Simulation	3.01	3.03	2.96	0.655	2.76	3.29	<0.001	2.74	3.23	0.001
System Integration	2.83	2.83	2.82	0.993	2.64	3.03	0.013	2.53	3.06	0.001
Cloud Technologies	3.13	3.10	3.23	0.404	3.16	3.10	0.696	3.08	3.17	0.598
Augmented Reality	2.79	2.77	2.84	0.673	2.81	2.78	0.599	2.82	2.77	0.538
Machine to Machine (M2M)	2.35	2.29	2.51	0.189	2.06	2.66	<0.001	1.95	2.65	<0.001

*Abbreviations: SS: Social Sciences; SaE: Science and Engineering; SaHS: Social and Humanities Sciences; ENG: Engineering; U: Mann-Whitney U test

When compared the students' knowledge level in Industry 4.0 technologies according to their education level, significant difference occurs only for Big Data (sig = 0.035). Ph.D. students ($\bar{x}$ = 3.37) are more knowledgeable in big data than master students ($\bar{x}$ = 3.03). This can be explained by the fact that Ph.D. students are more experienced in the business world. In any case, both social sciences and engineering education, in modern working conditions implies the adoption of diverse knowledge and skills that would contribute to a better understanding of problems in work (Mitrović Veljković et al., 2020). PhD students, who have been studying for many years and have a longer period of familiarity with the business world, should have more information about new business practices as big data.

On the other hand, the results indicate that postgraduate students' knowledge levels in the other Industry 4.0 technologies don't change according to their education level. The results of Mann-Whitney U tests show that (Tab. 4), significant differences occur in knowledge levels in the same 7 of the industry 4.0 technologies (Additive Manufacturing - 3D Printers, Internet of Things, Smart Factories, Autonomous Robots, Simulation, System Integration, Machine to Machine) according to students' institute and bachelors' degree.

The students who are studying at Science and Engineering Institute have more knowledge in these technologies than the students who are studying at Social Sciences Institute. Likewise, the students who have bachelors' degree in Engineering have more knowledge in these technologies than the students who have bachelors' degree in Social and Humanities Sciences. Students' knowledge levels in the other 4 Industry 4.0 technologies (Cyber physical Systems/Cyber Security, Big Data, Cloud Technologies, Augmented Reality) don't differ according to their institute and bachelors' degree. To predict this result, as it has been revealed in previous studies that the gap between the qualifications of current graduate students and the needs of the industry is a very important issue for the engineering programs (Pattanapairoj et al., 2021).

In this research postgraduate students' opinions toward advantages and disadvantages of Industry 4.0 have also been investigated. 17 advantages and 8 disadvantages of Industry 4.0 were included in the questionnaire. The students were asked to identify their opinion in a five-point Likert scale (1 = completely disagree; 5 = completely agree) for each of the advantages and disadvantages. The mean values of the students' opinions toward advantages and disadvantages of Industry 4.0 are shown on Figure 2 and Figure 3 respectively.

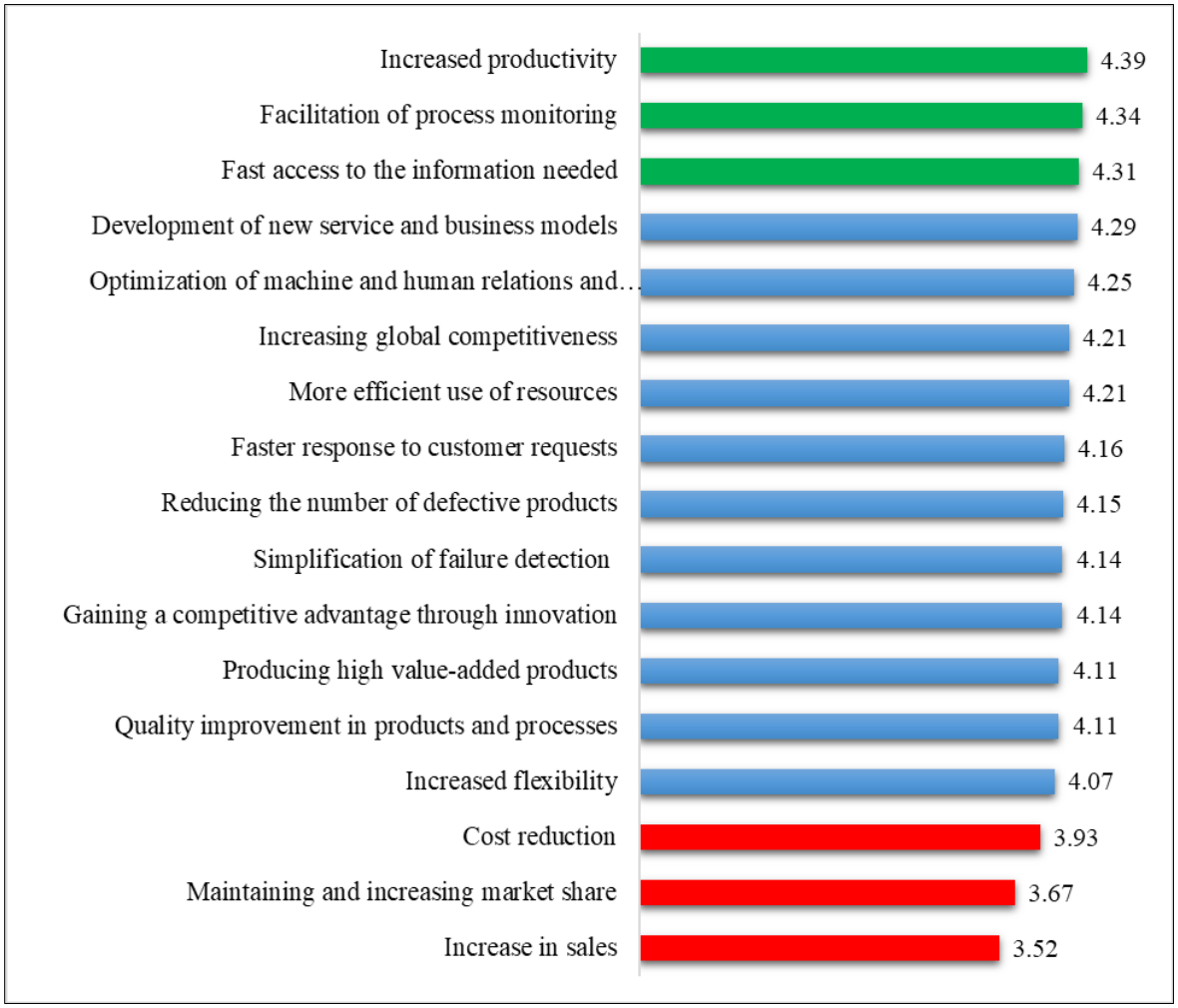

Figure 2: Students' perceptions toward advantages of Industry 4.0

According to the Figure 2, the importance of the advantages of Industry 4.0 are ranging from 3.52 to 4.39. According to the postgraduate students, 3 most important advantages of Industry 4.0 are "Increased productivity ($\bar{x}$ = 4.39)", "Facilitation of process monitoring ($\bar{x}$ = 4.34)" and "Fast access to the information needed ($\bar{x}$ = 4.31)" respectively. These results are consistent with the assertions of Rüßmann et al. (2015) that technological developments have created significant increases in productivity since the first industrial revolution (2015) and support the propositions of Reis and Gins (2017) that today, almost every stage of production system can be monitored with technologies such as cloud, which enables easy access to any information in a business (Reis and Gins, 2017).

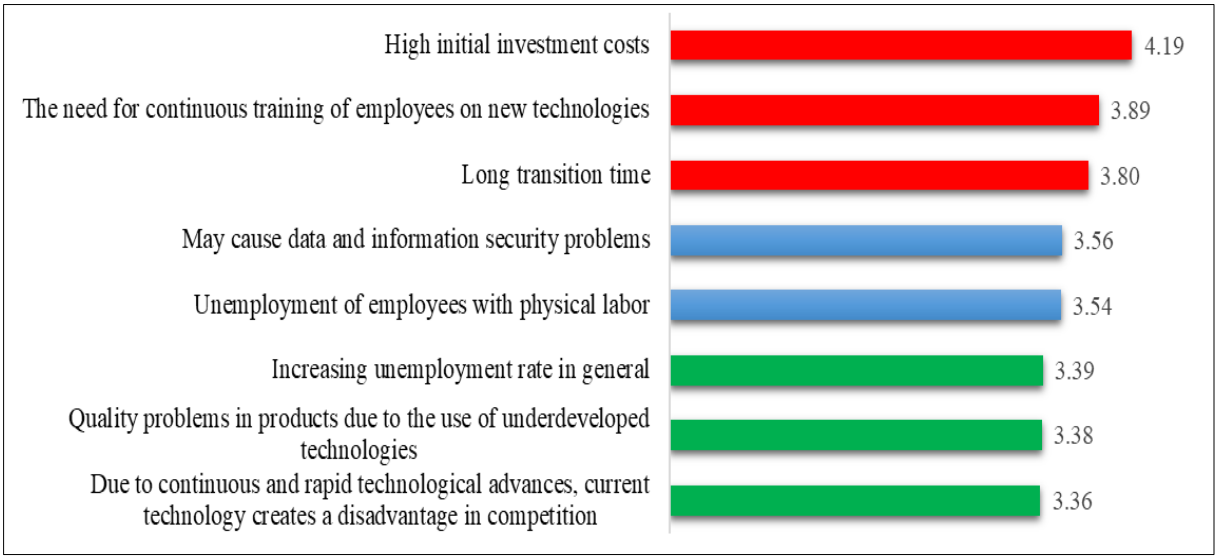

Figure 3: Students' perceptions toward disadvantages of Industry 4.0

According to the Fig. 3, the importance of the disadvantages of Industry 4.0 are ranging from 3.36 to 4.19. According to the postgraduate students, 3 most important disadvantages of Industry 4.0 are "High initial investment costs ($\bar{x}$ = 4.19)", "The need for continuous training of employees on new technologies ($\bar{x}$ = 3.89)" and "Long transition time ($\bar{x}$ = 3.80)" respectively. Research also supports this view of students. The applications of Industry 4.0 cannot be provided with the equipment currently available in the enterprises. In addition, employees who can work with these applications should also receive training. These issues represent the main obstacles and reservations about Industry 4.0 (Sommer, 2015).

Since industry 4.0 itself is considered a technological revolution, it provides a gateway between today's production order and future revolutions and provides opportunities for all social and economic developments. Although Industry 4.0 is clearly very promising for the economy and society, its deployment has also raised concerns regarding its potential negative economic and social impacts. A main concern is the impact of Industry 4.0 on employment and jobs (Cézanne et al., 2020). In the case of Industry 4.0, new technology mainly increases productivity. As companies become more productive, they become more competitive and are likely to hire more higher-skilled workers in better jobs (Vieira et al., 2022). Increasing labor competition for better job opportunities also demands more skills and being more accustomed to Industry 4.0 practices. For this reason, it is important for the future workforce to have knowledge about these applications and to have a high belief in their usability. In economic sense, Industry 4.0 will address and create solutions for some of the challenges facing the world today such as resource and energy efficiency, urban production, and demographic change. Industry 4.0 enables continuous

resource productivity and efficiency gains to be delivered across the entire value network which allows sustainable production as well.

5. Conclusion

The present study mainly focused on the concept of fourth industrial revolution, called Industry 4.0 which has recently received more attention from academicians and practitioners. Industry 4.0 has existing and potential technological, economical, and social impacts on society and individuals. Although there have been studies regarding to the technological and economical aspects of Industry 4.0, there is a lack of understanding of the social impact of it. In this sense, the main contribution of this study is to provide new evidence on the technological, economical, and social impacts of Industry 4.0 on society and individuals with a holistic approach by questioning the perceptions of university students and examining the advantages and disadvantages of Industry 4.0 as well.

The results of the study indicate that the sampled graduate students have a moderate knowledge about Industry 4.0. With this respect, the practical policy implication of this study might be needed to increase the level of knowledge related to the fourth industrial revolution, primarily on basic concepts, and then to improve and implement the technologic issues. Students should be introduced to technology and asked to incorporate it into their educational processes, which can serve as a bridge to adapt the future workforce to changing technological developments.

Likewise, the previous studies, this study has several limitations. First, the narrow focus of examining only one of the largest universities in Turkey precludes the generalization of the findings to other universities. It would be useful in future studies to collect data from other universities in Turkey. Moreover, future research should endeavour to examine other emerging and developed country combinations to draw a big picture of the issue.

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GENİŞLETİLMİŞ ÖZET: Günümüz toplumu her alanda teknolojik gelişmeleri yansıtan bir inovasyon süreci yaşamaktadır (Mariani ve Borghi, 2019). Sanayi yüzyıllar boyunca gelişmiş ve günümüz ihtiyaçlarını karşılamak için Endüstri 4.0'ı doğurmuştur. Endüstri 4.0 konsepti, Alman ekonomik kalkınma planının bir parçası olarak 2011 yılında Hannover Fuar Etkinliği ile tanıtılmış ve fuar aynı zamanda Endüstri 4.0'ın başlangıcı olarak da sembolize edilmiştir (Qin vd., 2016). Endüstri 4.0 veya dördüncü sanayi devrimi imalat sanayinde ortaya çıkmıştır ve esas olarak otomasyon ve veri değişimine dayalıdır. Büyük bir yenilik gibi göründüğü için devrim olarak adlandırılır ve bu nedenle bu alandaki makaleler Endüstri 4.0'ın yenilik boyutuyla alakalıdır. Endüstri 4.0 literatürü çoğunlukla kavramın inovasyon yönlerine odaklanmaktadır. Ancak ani teknolojik gelişmelerin ve dijitalleşmenin toplum ve bireyler üzerindeki etkisi yeni bir araştırma alanı oluşturmaktadır. Literatürdeki boşluğu doldurmak için bu çalışma, toplumun mevcut veya gelecekteki işgücünü oluşturan lisansüstü öğrencilerin algılarından hareketle Endüstri 4.0'ın gerekliliğini, avantajlarını ve dezavantajlarını analiz etmeyi amaçlamaktadır.

Bu amacı gerçekleştirmek için öncelikle Endüstri 4.0'ın gerekliliği, avantajları ve dezavantajları ile ilgili literatür taranmıştır. Literatür taramasına dayalı olarak, Endüstri 4.0'ın bileşenleri olarak bilinen yenilikçi teknolojiler ele alınmıştır. Bu teknolojiler şu şekilde sınıflandırılmıştır:

Eklemeli Üretim-3 Boyutlu Yazıcılar: Eklemeli üretim, 3 boyutlu malzemeler üretmek için malzemeyi katmanlar halinde biriktiren ve parça üretme süresini kısaltan bir dizi işlemdir (Anand et al. 2018).

Nesnelerin İnterneti: IoT (Nesnelerin İnterneti), karmaşık sistemlerin çevik yönetimi için dijital dünya ile gerçek dünyayı birbirine bağlayabilen nesnelerin veya sensörlerin kullanılmasıdır (Caron et al. 2016).

Akıllı Fabrikalar: Akıllı fabrikalar, fiziksel nesneleri ve insanları, IoT, CPS (siber fiziksel sistemler) vb. gibi yenilikçi teknolojilerle üretim sürecinin entegre bir parçası haline getirerek merkezi kontrolü merkezi olmayan zekaya dönüştüren yeni bir fabrika türüdür (Shrouf, Ordieres ve Miragliotta, 2014). Endüstri 4.0 ile fabrikalar daha esnek, daha dinamik, daha akıllı, kendi kendini optimize eden ve otomatikleşen hale gelir (Lu, 2017).

Siber Fiziksel Sistemler - Siber Güvenlik: CPS, fiziksel ve sanal dünyayı birleştiren ve yenilikçi çalışma biçimleri geliştiren endüstriyel otomasyon sistemleridir (Hofmann ve Rüsch, 2017).

Büyük Veri: Çeşitli verilerden oluşan veri kümeleri, süreç ve ürün kalitesini iyileştirmek üzere izleme, kontrol ve optimizasyon için kullanılabilir (Reis ve Gins, 2017).

Otonom Robotlar: Üretim süresini kısaltmak için mobil desteğe ihtiyaç duyan veya daha sonraki işlemler için başka bir makineye hazır hale getiren, dağıtık bir üretim hattının parçası olan akıllı makinelerdir (Gonzalez vd., 2017).

Simülasyon: Tüm endüstriyel süreçleri optimize etmek için farklı bilgisayar programları entegre edilerek üretim süreçleri ve performansları kolayca simüle edilir (Akgül, Akbaş ve Gümüş, 2018).

Sistem Entegrasyonu: Üreticiler ancak her bir prosesin birbiriyle entegre olduğu sistemler ile piyasanın taleplerini en kısa sürede ve en iyi şekilde karşılayabilirler (Doh vd., 2016).

Bulut Teknolojileri: Üretim, farklı bulut teknolojileri ile üretim süreçlerini hızlandırır ve varlıklara sanal erişim sağlar (Pedone ve Mezgar, 2018).

Artırılmış Gerçeklik (AR): AR, sanal bilgiyi gerçek ortamla bütünleştirir ve böylece sanal gerçekliğin o anın koşullarında var olarak algılanmasını sağlar.

Makineden Makineye Erişim (M2M): Makineden makineye erişim, nesnelerin interneti ile giderek daha popüler hale gelmiştir (Tagarian ve Ghahfarokhi, 2019).

Öğrencilerin Endüstri 4.0 konusundaki bilgi düzeyleri ile Endüstri 4.0'ın gerekliliğine yönelik algıları arasındaki ilişkinin varlığını belirlemek üzere 202 lisansüstü öğrencisine online anket uygulanmış ve korelasyon analizi gerçekleştirilmiştir. Araştırmanın sonuçları, örneklemde yer alan öğrencilerin Endüstri 4.0'ın son derece gerekli olduğuna inandıklarını göstermektedir. Bu çalışmanın bir başka ilginç sonucu da öğrencilerin Endüstri 4.0 konusundaki bilgi düzeylerinin öğrenim gördükleri enstitüye göre farklılık göstermemesine rağmen Endüstri 4.0'ın gerekliliğine olan inançlarının farklı çıkmasıdır. Son olarak, Endüstri 4.0'ın en önemli dezavantajı olarak "yüksek ilk yatırım maliyetleri" öne çıkarken, Endüstri 4.0'ın en önemli

avantajını "verimlilik artışı" temsil etmektedir. Endüstri 4.0'ın toplum ve bireyler üzerindeki, mevcut ve potansiyel teknolojik ve ekonomik yönleriyle ilgili çalışmalar olmasına rağmen, bunun sosyal etkisini anlamak konusunda bir eksiklik söz konusudur. Bu boşluğu doldurmak için bu çalışma, lisansüstü öğrencilerin algılarını sorgulayarak ve Endüstri 4.0'ın avantaj ve dezavantajlarını da inceleyerek Endüstri 4.0'ın toplum ve bireyler üzerindeki teknolojik, ekonomik ve sosyal etkilerine bütüncül bir yaklaşımla odaklanmaya çalışmaktadır.

EXTENDED ABSTRACT: Today's society has been experiencing an innovation process that reflects technological developments in every field (Mariani and Borghi, 2019). Industry has evolved over the centuries and gave birth to Industry 4.0 to meet today's needs. The concept Industry 4.0 was introduced with the Hannover Fair Event in 2011 as part of the German economy development plan, and the fair also symbolized as the beginning of Industry 4.0 (Qin et al., 2016). Industry 4.0 or fourth industrial revolution arose in manufacturing industry, and it mainly based on automation and data exchange. It is called as a revolution since it seems like a big innovation and therefore the articles in this area are relevant to its innovation dimension. The literature on Industry 4.0 mostly focuses on the innovation aspects of the concept. However, the impact of sudden technological developments and digitalization on society and individuals constitutes a new field of research. To fill the gap in the literature, this study aims to analyse the necessity, advantages and disadvantages of Industry 4.0 based on the perceptions of graduate students who constitute the existing or future workforce of the society. To accomplish this aim, first the literature about the necessity, advantages, and disadvantages of Industry 4.0 was reviewed. The innovative technologies known as the components of Industry 4.0 were discussed based upon the literature. These technologies were classified as follows:

Additive Manufacturing - 3D Printers: Additive Manufacturing is a series of processes that accumulate material in layers to produce 3D material and shorten the time to produce (Anand et al., 2018).

Internet of Things: The IoT (Internet of Things) is the use of objects or sensors that can connect the digital world and the real world for agile management of complex systems (Caron et al., 2016).

Smart Factories: Smart factories are a new kind of factories that transform central control into decentralized intelligence by making physical objects and people an integrated part of the production process with innovative technologies such as IoT, CPS (Cyber Physical Systems), etc. (Shrouf et al., 2014). With Industry 4.0, factories become more flexible, more dynamic, smarter, as well as self-optimizing and automating (Lu, 2017).

Cyber Physical Systems - Cyber Security: CPS are industrial automation systems that combine the physical and virtual world and develop innovative forms of operation (Hofmann and Rüsch, 2017).

Big Data: The datasets formed by various data can be used for monitoring, control and optimization in order to improve process and product quality (Reis and Gins, 2017).

Autonomous Robots: These are the smart machines that are part of a distributed production line that requires mobile support to shorten production time or make ready them to another machine for further processing (Gonzalez et al., 2017).

Simulation: Production processes and performances are easily simulated by integrating different computer programs to optimize all industrial processes (Akgül et al., 2018).

System Integration: Manufacturers can only meet the demands of the market in the shortest time and in the best way with systems where each process is integrated with each other (Doh et al., 2016).

Cloud Technologies: The production context accelerates production processes with different cloud technologies and provides virtual access to assets (Pedone and Mezgar, 2018).

Augmented Reality (AR): AR integrates virtual information into the real environment and thus allows the virtual reality to be perceived as present in the conditions of the moment.

Machine to Machine (M2M): Machine-to-machine access is becoming more and more popular with the Internet of objects (Tagarian and Ghahfarokhi, 2019).

To identify the existence of relationship between students' knowledge level in Industry 4.0 and beliefs towards necessity of Industry 4.0, an online survey was conducted with 202 graduate students and a correlation analysis was run Results of the study indicate that sampled students believe that Industry 4.0 is highly necessary. Another interesting result of this study is that the knowledge level in Industry 4.0 of students does not differ according to the institute where they study, but their belief towards necessity of Industry 4.0 differs. Finally, "increased productivity" represents the most important advantage of Industry 4.0 whereas "high initial investment costs" stands out as the most important disadvantage of Industry 4.0. Although there have been studies regarding to existing and potential technological and economical aspects on society and individuals, there is a lack of understanding of the social impact of it. To fill this gap, this study attempts to focus on the technological, economical, and social impacts of Industry 4.0 on society and individuals with a holistic approach by questioning the perceptions of university students and examining the advantages and disadvantages of Industry 4.0 as well.