Are Students Ready for Working in the Industry 4.0 Environment - A Comparative Study of Ukraine and Poland

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Abstract

Companies all over the world benefit from Industry 4.0, to fully harness its potential they need a skilled workforce. Hence, the goal of the paper is to recognize whether students, who represent the future workforce, are ready for the new technological conditions and challenges that these bring. Education at the academic level should follow and, in some cases, precede business conditions to ensure that students have the skills required in the labor market after graduating, both in hard skills and soft skills areas.

Keywords: labor market, Industry 4.0, students' readiness, higher education

1. Introduction

Today, the world is on the verge of global changes in all spheres of social life. These changes are related to the development of the Fourth Industrial Revolution (Industry 4.0), which began in 2011 and is changing the world beyond recognition [7], [19], [23]. This fourth era of technological change presents multifaceted challenges for both industry and educational institutions [30], thereby intensifying the demand for a workforce equipped with advanced, future-oriented competencies. This paper is motivated by the imperative to assess whether current students – the future labor force – are being adequately prepared through academic education to meet the demands and challenges posed by these technological advancements. Only qualified and well-educated employees will be able to control, adapt to, and further develop these advanced technologies [4,5]. Emerging technologies exert a substantial influence on educational practices, curricula, and the development of essential digital and interdisciplinary competencies [13]. In light of the transformative impact of Industry 4.0 on the labor market and education systems, it is crucial to understand how well students – particularly in transitioning economies like Poland and Ukraine – perceive these changes and how prepared they feel to enter a technology-driven work environment.

The research aims to analyze the attitudes of students from Poland and Ukraine concerning Industry 4.0, as well as to verify their readiness to work under the conditions of the Fourth

Industrial Revolution. The term "readiness" means that the student has knowledge of this concept and its advanced technologies and has practical experience that can be used in the industrial sector based on advanced information technologies, automation, robotics, artificial intelligence, data analysis, Internet of Things (IoT), etc. The research problem therefore concerns the question of whether students from the surveyed countries are ready for work in the conditions of

The structure of this article has been divided into several sections. This section is an introduction to the issues discussed in the article. The literature review section characterizes Industry 4.0 as a new paradigm in current reality, as well as discusses the changes in education that have occurred as a result of the development of technology. The methodological section presents the methods that were used to achieve the goal set in the article. The results section illustrates and discusses the results of the survey conducted among students from Poland and Ukraine. In the discussion section, conclusions from the completed research were drawn and their importance was indicated. The summary section, in turn, is devoted to recommendations regarding the issues raised in the work, as well as limitations and further directions of research.

2. Theoretical background

The phenomenon of Industry 4.0 is the subject of fierce disputes among many researchers from various fields of knowledge [31]. Points of view on its perspectives and impact on the state of the modern world are sometimes diametrically opposed: from the claim that Industry 4.0 is a new paradigm of technological development, to the interpretation of this phenomenon as ideological propaganda, especially in the preselection period [7].

The general idea of Industry 4.0 is to use modern technologies to boost the efficiency and competitiveness of the company [32], [41], which creates many new opportunities, but it produces at the same time many challenges [16,17], [38] affecting modern education to a considerable extent [24], [35]. With the advent of Industry 4.0, all sectors of society have been forced to adapt by making greater use of digital technologies to continue operating sustainably.

Research indicates that university graduates do not have the appropriate skills and competencies required in the Industry 4.0 labor market [8], [34]. Key requirements employers may have for students include: technical skills [27], adaptability and learning [1], communication skills [39], analytical thinking and problem-solving [28], soft skills [44], cyber security knowledge [26], global thinking, the ability to work with large amounts of data [22], and the ability to work in virtual teams and remotely [12]. Hence, universities should follow the needs of Industry 4.0 [20], [33], [21], [24].

Moreover, professions will likely change under the influence of the challenges of digitalization, but they will certainly continue to set the basic qualifications framework for work in industry, also with respect to their dynamics [42], [46], [48], [18], [24]. Therefore, changes in educational programs are necessary to prepare students for entering the labor market.

Students' knowledge and readiness for Industry 4.0 can be determined by assessing their level of technical skills, teamwork skills, ability to adapt to new technologies, and quick learning [34]. The research shows that many students are aware of Industry 4.0, but lack in-depth knowledge and understanding of its applications, as analyzed in Namibia [45], South Korea [43], Italy [29], Oman [2].

There is a notable gap between the skills provided by universities and those required by industry, necessitating a more holistic approach to education, which includes feedback from industry professionals [51], [25], [34], [36]. Modern student education therefore requires a harmonious combination of cognitive, communication, and analytical skills, as well as the ability to quickly adapt to changes in the rapidly evolving world of technology [28], [37].

The development of technology in the context of modern student education requires a harmonious combination of cognitive, communication, and analytical skills, in addition to the ability to quickly adapt to changes in the rapidly evolving world of technology, hence there are numerous examples of Industry 4.0 educational programs [14], [37], [49], [50], [11].

There are several studies on students' knowledge and perception of Industry 4.0, including Czerwinska [10] (which focuses on computer science students at Lublin University of Technology, and therefore renders it limiting compared to the scope of the research presented in the paper and mostly referring to IT aspects of Industry 4.0), and Bilotta et al. [6], whose

study is dedicated to students of tourism in the context of Industry 4.0. Other authors focus on country-specific aspects [45]. Some researchers e.g. Vilalta-Perdomo et al. [47] and Chakraborty et al. [9] focus on methods to be used when introducing the Industry 4.0 concept to students, including contemporary techniques such as challenge-based learning. The research presented in this paper covers two countries and business-orientated study fields, which makes it broader and more universal.

3. Research method

The research methodology was designed to achieve the goal set in this article and comprised several stages. The first stage of the work was a literature review. Based on this review and secondary research, Industry 4.0's impact on society was analyzed, as well as the main market requirements originating from the new paradigm in technological development. An equivalent stage involved appointing a research group and conducting empirical research.

The empirical research was a survey with a set of brainstormed questions referring to the purpose of the research – single and multiple choice questions with the option of providing one's own answer. The surveying tool used was a Google form. Using the Google tool enabled web distribution of the form, and consequently facilitated international research range, collecting answers fast, without additional cost. The target group of the study was students of neighboring European countries – Poland and Ukraine. The CAWI technique (Computer-Assisted Web Interview) was selected as the research technique, as it is one of the most popular and fastest-growing research techniques. What is more respondents prefer CAWI as they can choose the date and pace of completing the form, they can do it at any place, using computers and mobile devices. The tool was tested in the pilot study – 10 students received the survey and were asked to answer the questions and comments on their clarity, quality and relevance. Their comments were used to improve the tool that was widely distributed with emails and social media (Facebook and Telegram groups associating students).

The selection of the research sample was guided by the primary objective of the study—to assess students' perspectives on the impact of Industry 4.0 and associated market demands in the context of contemporary technological transformations. As the research was the part of the Polish-Ukrainian research project, these countries were targeted. We wanted to reach diverse group striving for diversity in terms of: age – capturing different academic stages, from early undergraduate to graduate levels; gender – ensuring both male and female representation, though with noticeable imbalances (e.g., higher female participation in Ukraine); mode of study – including both full-time and part-time students; level of education – covering Bachelor's and Master's degree programs. The survey was open for students of all disciplines and courses. This disciplinary diversity allows for nuanced insight into how Industry 4.0 is perceived in general, across distinct academic and professional preparation areas, not only addressing the research to technically oriented students but also reaching other groups.

The next stage of the research work was analyzing and interpretating the data obtained in the course of the survey. Additionally, statistical analysis (ANOVA) was used to identify relationships between selected variables. Although there are many more advanced statistical methods that can be used to analyze group differences (e.g., MANOVA, regression modeling, or structural equation modeling — which often require larger samples, more complex assumptions, and are more difficult to interpret and communicate to a broad audience), ANOVA remains one of the most widely used and well-established techniques in recent research focusing on students' perceptions and opinions [3], [15], [52]. More importantly, we chose ANOVA for this study because it allows us to determine whether there are statistically significant differences between the student groups analyzed, while providing an optimal balance between the reliability of the analysis and the clarity of result interpretation. Furthermore, our primary goal was to identify general patterns and significant differences in attitudes and readiness among students from different groups, rather than to construct a predictive or causal model — for which ANOVA is appropriate and sufficient.

The last stage was a discussion based on the results of the data analysis. During this discussion, the importance of the results and their potential implications were explained, as well as inferences covering key aspects, limitations, and further directions of possible research.

4. Results

The respondents were Polish and Ukrainian students studying full-time and part-time at state and private universities were invited to participate in the survey – a total of 915 students from Poland and 1156 students from Ukraine. Participation was anonymous. Given that in the 2023/2024 academic year there were 1223600 students in Poland and 1052000 students in Ukraine, and that parameters such as a maximum error of 4% and a confidence level of 98%, it was specified that the required number of respondents should be at least 845. This assumption was met for both groups, therefore confirming the representativeness of these samples.

The structure of the respondents who participated in the survey is presented below. By analyzing the respondents in terms of their age, it should be noted that the largest number of students from Poland was aged 19 to 22 (60%). Another group was students aged 23 to 26 years (31%). In the case of Ukrainian students, the situation is slightly different, as the largest group is students up to 18 years of age (63%), with the next group according to the number of answers provided being students between 27 and 29 years of age (27%). The differences between the two countries may stem partly from the fact that Ukrainian students start their studies at 17-18 years of age, while in Poland the typical age for most students is 18-19.

In terms of gender, more men than women participated in the survey on the Polish side (58% and 39.5%, respectively), with 2.5% of the respondents preferring not to state their gender. On the Ukrainian side, more women than men participated in the survey (62.5% and 33.5%, respectively), with 4% not indicating their gender.

In Poland, students studying in the first year of engineering or bachelor's degree studies (35%) participated in the survey, while in Ukraine students in the second and third year of engineering or bachelor's degree studies (30%, and 29%, respectively) participated in the survey. It is worth noting that on the Polish side, students studying on master's degree courses constituted a much larger (almost three times larger) group of respondents with regard to the general population compared to second-cycle students in Ukraine (24% and 9%, respectively).

In Poland, 704 students who participated in the survey (77%) are full-time students, and 211 students (23%) are part-time students. In Ukraine, 1,031 students who participated in the survey (89%) are full-time students and 125 students (11%) are part-time students.

The survey addressed to students from Poland and Ukraine included 13 questions. The questions posed to respondents are provided in Appendix 1. The results obtained in the course of the survey are presented below. The raw data from the survey can be found in Appendix 2 and Appendix 3.

The first question of the survey concerned verifying students' knowledge of the concept of Industry 4.0. 331 students (36%) from Poland indicated that they were familiar with the concept, 374 students (41%) indicated that they did not know such a concept, and 210 students (23%) were unsure how to answer the question. In Ukraine, 274 students (24%) declared that they were familiar with the concept of Industry 4.0, 555 students selected a negative answer (48%), and 327 students indicated that they were not sure of the answer (28%). The next part of the study focused only on students familiar with the Industry 4.0 concept and those who were unsure about it, in total, 541 students from Poland and 601 from Ukraine.

In the second question, students were asked about their associations with the concept of Industry 4.0 We have listed the main pillars of Industry 4.0 and the potential consequences of their implementation for companies, as described in previous studies [40]. This was a multiple-choice question limited to 3 responses. The groups surveyed from both countries most often indicated that they associate the term Industry 4.0 with an industry based on automation, robotization, and artificial intelligence. It should be emphasized that these are the correct associations, since robotization, automation, and artificial intelligence constitute the basic pillars of Industry 4.0.

Next, the respondents were asked if they had participated in seminars, workshops, training, and lessons thematically related to Industry 4.0. The analysis revealed very similar results from both countries: in Poland 110 students (20%) had participated in such events, and in Ukraine 104 students (17%). Students attending Industry 4.0 events were asked what their topic was (multiple responses were allowed). The data obtained show that most of the events concerned information on the basics of Industry 4.0, the possibilities of using solutions and tools of a given concept, and the opportunities and threats on the Industry 4.0 labor market. However, far fewer

events concerned practical contact with Industry 4.0 solutions.

The next question was aimed to verify whether the students had or were undertaking a job/apprenticeship/internship in a company using elements of Industry 4.0. Concerning the question posed, the situation is slightly better in the case of Poland, as 22% of respondents (119 students) have undertaken such activity, with 13% of Ukrainian respondents having done so (79 students). Additionally, students were asked about the duration of these activities. Among students taking up a job, apprenticeship, or internship in Poland, 67% had carried out this activity for up to 1 year. In Ukraine, this percentage of respondents is 82%. However, the dominant feature in both countries is undertaking the activity for 3 months: 36% of respondents in Poland and 38% of respondents in Ukraine.

The next two questions concerned the students' perception of Industry 4.0 as a new phenomenon in the labor market. They were asked how they assess the phenomenon of Industry 4.0 on the labor market and whether they perceive it as an opportunity or a threat. The findings show that in Poland 309 out of 541 students (57%) believe that Industry 4.0 to be a rather positive phenomenon in the labor market. Similarly, in Ukraine 364 out of 601 students (61%) agree with his assessment. 16% of Polish students state that Industry 4.0 is a positive phenomenon, with Ukrainian students confirming this view in 18% of cases. It should be emphasized that a very small percentage of students in both countries state regard Industry 4.0 as a negative or rather negative phenomenon (4% in Poland and 5% in Ukraine, respectively).

On the question of whether Industry 4.0 is a labor market opportunity or a threat, the majority of students in both groups indicated that this is rather an opportunity (55% of Polish students and 56% of Ukrainian students). 20% of Polish students and 13% in Ukraine agree that Industry 4.0 is definitely positive in Poland. It is assessed as a threat by 11% of respondents from Poland and 15% of respondents from Ukraine.

Students' concerns about the future of the labor market in relation to Industry 4.0 were addressed by the next question. The distribution of students' answers in both countries was similar: in Poland, 39 students (7%) definitely have no concerns about the future in the reality of Industry 4.0, 253 students (47%) have no concerns at all, 223 students (41%) have some concerns in this context, and 26 students (5%) definitely have concerns about the future in the new conditions on the labor market; in Ukraine, 79 students (13%) are definitely not worried about the future in the reality of Industry 4.0, 276 students (46%) are rather not worried, 202 students (34%) have some concerns in this context and 44 students (7%) definitely have concerns about the future in the new conditions on the labor market.

With the exception of those who definitely indicated that they had no concerns about the future under the conditions of the new paradigm, the students were then asked to indicate aspects that would help alleviate their fears about Industry 4.0 in the context of the future labor market. Students could select up to three answers. For Polish students, their fear of working in the conditions of Industry 4.0 could be reduced primarily by including more classes in the curriculum that develop technical skills, such as 3D printing, simulation, etc. (308 responses; 57%), in addition to participating in real projects related to Industry 4.0 (270 responses; 50%), and enabling students to spend more time in real enterprises, e.g. through internships (252 responses; 47%). In turn, Ukrainian students indicated that to reduce their fears, the most important thing for them is to include more classes that develop soft skills in (283 responses; 47%), allowing them to spend more time in real companies (252 responses; 47%) and participate in real projects related to Industry 4.0 (222 responses; 37%).

In the next question, respondents were asked whether they see the need to expand their knowledge about Industry 4.0 in the context of current market realities. The vast majority of students – more than 80% – both in Poland (90%) and in Ukraine (83%) stated that they see such a need. The distribution of responses proves the topical nature of this issue and the need to develop it in the educational context.

The last question concerned the students' self-esteem. Respondents were required to assess the extent to which they are prepared and ready for the labor market in the conditions of Industry 4.0. A small percentage of students in both groups (in Poland 16%; in Ukraine 12%) indicated that they were very well or well prepared to work under the conditions of the new concept. A significant proportion of students in both cases (45% in Poland, and 41% in Ukraine) signaled that they were averagely prepared to work in such conditions. An appreciable proportion of

students in Poland (39%) indicated that they are only slightly prepared or not at all prepared to work in the conditions of Industry 4.0. In Ukraine, in turn, this group accounted for almost half of the respondents (47%), clearly indicating the need to focus considerable attention on the need to prepare students for work in the new reality.

5. Discussion

In the context of the results obtained, information about students' internships, work, or apprenticeships in the industry using elements of Industry 4.0 is important, as this may constitute a valuable alternative to standard classes and dedicated events. Unfortunately, in both countries, students' exposure to the practical aspects of Industry 4.0 in industrial settings is very limited, with a slight advantage for Poland (22% of respondents in Poland vs. 13% in Ukraine). A slightly higher percentage of students with practical experience in Industry 4.0 in Poland than in Ukraine may indicate better-developed collaboration between universities and industry or a greater number of companies implementing Industry 4.0 elements in Poland. It is worth noting that approximately 70% of students in Poland and 80% of students in Ukraine have practical experience lasting not longer than 1 year. The possibility of acquiring knowledge and skills about the modern tools of Industry 4.0 through work, apprenticeships, and internships is dictated not only by the willingness of students to acquire new competencies and skills but also by the technological advancement of enterprises in a given country. Based on the obtained results, it can be concluded that universities and enterprises should undertake more intensive efforts to create and expand opportunities for students to gain practical experience in real industrial settings. Only in this way will it be possible to effectively prepare graduates to work in a modern Industry 4.0 environment and to increase their competitiveness in the labor market.

To quantify the relationship between the dependent variable, which was the student's individual assessment in the context of readiness for work under the conditions of Industry 4.0, and two independent variables – participation in seminars/workshops/training/classes on topics related to Industry 4.0 and taking part in work/work placement/internship in a company using elements of Industry 4.0 – an analysis of variance was carried out. The results of the statistical analysis in both countries indicate that the model is significant because the Significance F value is much smaller than 5% (Table 1).

The P-value in relation to individual independent variables, both in the case of students from Poland and in the case of students from Ukraine, is also much smaller than 5%, which means that the relationships between dependent and independent variables are statistically significant.

Table 1. ANOVA – Poland and Ukraine

	df	**SS**	**MS**	**F**	**Significance F**	
Regression	PL: 2 UA: 2	PL: 41.184 UA: 21.369	PL: 20.592 UA: 10.685	PL: 29.256 UA: 13.020	PL: 8.686E-13 UA: 2.918E-06	
Residual	PL: 538 UA: 598	PL: 378.672 UA: 490.731	PL: 0.704 UA: 0.821			
Total	PL: 540 UA: 600	PL: 419.856 UA: 512.100				
	Coefficients	**Standard Error**	**t Stat**	**P-value**	**Lower 95%**	**Upper 95%**
Intercept	PL: 2.522 UA: 2.418	PL: 0.043 UA: 0.042	PL: 58.012 UA: 57.495	PL: 1.12E-233 UA: 1.64E-247	PL: 2.437 UA: 2.336	PL: 2.608 UA: 2.500
Participation in seminars/workshops/training/classes related to Industry 4.0	PL: 0.429 UA: 0.283	PL: 0.091 UA: 0.103	PL: 4.704 UA: 2.751	PL: 3.24E-06 UA: 0.006	PL: 0.250 UA: 0.081	PL: 0.608 UA: 0.486
Taking part in work/ work placement/ internship in a company using elements of Industry 4.0?	PL: 0.448 UA: 0.369	PL: 0.089 UA: 0.115	PL: 5.050 UA: 3.205	PL: 6.074E-07 UA: 0.001	PL: 0.273 UA: 0.143	PL: 0.622 UA: 0.596

This analysis shows that in the absence of training/seminars/lessons/workshops, as well as the lack of a practical work placement in companies that implement elements of Industry 4.0, students will be poorly or averagely prepared to work in the conditions of Industry 4.0 (result for the dependent variable $y \approx 2.5$ for both study groups). The functions of the multiple ordinary

least squares (OLS) regression for students from Poland (1) and Ukraine (2) are as follows:

$$y_{(PL)} = 2.52 + 0.43x_1 + 0.45x_2 \quad (1)$$

$$y_{(UA)} = 2.42 + 0.28x_1 + 0.37x_2 \quad (2)$$

These results indicate that each instance of students participating in workshops/training/ lessons/seminars on Industry 4.0, as well as taking up work, apprenticeships/ work placements, or internships in companies implementing Industry 4.0 solutions, will result in students being prepared for the labor market under the conditions of the new concept. It should also be emphasized that implementing work/work placement/internship in a company operating in accordance with Industry 4.0 has a slightly greater impact on the preparation of students compared to participating in various types of workshops or training on the analyzed topics.

Throughout the research process, we strived to maintain academic integrity by adhering to ethical guidelines, ensuring methodological consistency, and upholding the highest standards of quality in data collection, analysis, and interpretation. Nevertheless, we acknowledge potential threats to the validity of the obtained results, including issues related to internal validity, which may be affected by the lack of random assignment and possible response biases. Although the survey underwent verification and piloting stages, variations in respondents' interpretations of certain questions may have influenced response consistency. Construct validity could also be challenged if key concept (such as Industry 4.0 readiness, perceived market expectations) were not uniformly understood across different cultural and educational contexts. Despite careful questionnaire design, such abstract terms may carry different meanings depending on the respondent's background. Statistical conclusion validity, while supported through the use of ANOVA, may be limited by unequal group sizes across demographic categories and fields of study, potentially introducing variability in the statistical power of certain comparisons.

6. Summary

The results of the conducted research clearly indicate that the knowledge and practical experience of students from both countries related to Industry 4.0 remain limited and insufficient to function in the current market conditions. This indicates a clear gap between academic education and industrial requirements. The research also indicates that despite the fact that students generally perceive Industry 4.0 positively, many of them still feel unprepared for the challenges it poses, especially in terms of technical and soft skills. The obtained results emphasize the importance of integrating both theoretical knowledge and practical experience to better equip students with knowledge about the changing labor market. Therefore, higher education institutions (HEIs) should support students in preparing for future work, as this is their primary task. This means that HEIs should adapt their current educational programs by incorporating a number of theoretical classes to familiarize students with the issue under consideration on a broader scale, as well as enabling students to develop practical skills to work in enterprises that have implemented Industry 4.0 solutions. In this context, it is recommended to create appropriate laboratories in HEIs where students could become familiar with the tools such as 3D, Virtual Reality, Digital Twin, Machine Learning, etc.

The general conclusion from the article is that modern education must keep up with changes in the business environment and offer knowledge and skills to enable HEI graduates to function effectively in the labor market under the conditions of Industry 4.0.

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Appendices

1. Appendix 1 – https://zenodo.org/records/15779039
2. Appendix 2 – https://zenodo.org/records/15779110
3. Appendix 3 – https://zenodo.org/records/15779119

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