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# THE MODERN WORKER IN THE CONTEXT OF INDUSTRY 5.0: BALANCING HUMAN, TECHNOLOGY, AND SUSTAINABLE DEVELOPMENT

ABSTRACT

The article examines the readiness of vocational education (VE) applicants and graduates in Ukraine to work under Industry 5.0 conditions. The study is motivated by the urgent need to shift vocational education from the technology-driven paradigm of Industry 4.0 toward a human-centered, sustainable, and resilient model, which demands the integration of new competencies. The primary objective was to assess the current level of preparedness among VE students and graduates, and to evaluate the balance between the technological, socio-emotional, and ethical (sustainable development) components of their professional competencies. A mixed-methods approach was employed, combining a quantitative online survey (n = 273) with qualitative semi-structured interviews (n = 15) of VE students and graduates. Key findings reveal an uneven level of readiness. While graduates demonstrate basic digital literacy, their practical experience with innovative technologies such as AI and robotics remains limited. Conversely, social and emotional skills – including teamwork, communication, and adaptability – were found to be relatively well developed. Despite high levels of environmental and social awareness among respondents, these principles are not yet sufficiently embedded in practical training. The study concludes that gaps exist in the integration of technological and ethical components, highlighting the need to strengthen practical technology courses and systematically incorporate sustainable development principles into VE curricula.

KEYWORDS

Industry 5.0, modern worker, vocational education, competencies, balance (people, technology, sustainable development).

## 1. Background Context

The concept of Industry 5.0 (I5.0) represents a new phase in the evolution of manufacturing, integrating advanced technologies with a human-centered approach and the principles of sustainable development. Unlike Industry 4.0, which primarily focused on automation and the digitization of processes, Industry 5.0 highlights the role of humans as active participants in production processes and decision-making, working in synergy with technology.

Ukrainian vocational education faces numerous challenges, including rapid digitalization, the automation of production, and the increasing need to develop new competencies aligned with the current demands of the labor market. Preparing qualified workers requires the integration of technological, social-emotional, and ethical skills, ensuring their competitiveness and adaptability in a rapidly changing environment.

In the present-day Ukrainian economy, workers need not only technical expertise but also the ability to collaborate effectively, think creatively and critically, and approach the social and environmental dimensions of their work responsibly. Educational institutions play a pivotal role in cultivating these competencies by fostering the integration of learning, practical experience, and personal development.

## 2 Literature Review

### 2.1. The Evolution of Industry 5.0 and Its Implications for Workforce Competence Development in the Ukrainian Vocational Education System

The concept of Industry 5.0 (I5.0) emerged as a response to the limitations of the previous industrial revolution (Industry 4.0), which, while emphasizing digitalization and automation, often overlooked the human factor and the principles of sustainable development. I5.0 shifts the focus toward human-centered approaches, sustainability, and the broader resilience of production systems and society [1]. This paradigm involves a symbiotic collaboration between humans, machines, and intelligent systems, where technologies, including artificial intelligence (AI) and robotics, are employed to enhance rather than replace human capabilities [2, 3].

Industry 5.0 represents a strategic vision first articulated by the European Commission, aiming to empower industry to achieve social and environmental objectives beyond traditional measures of productivity and efficiency [4]. Its distinguishing feature lies in placing humans at the core of production processes, with innovation directed toward creating systems that are sustainable, ethical, and socially responsible [1, 5]. Consequently, I5.0 introduces new paradigms for the labor market, necessitating substantial changes in employment structures and the qualifications required of the workforce.

The implications of I5.0 for education are profound. Educational institutions, particularly within the vocational education (VE) sector, must realign their curricula to prepare workers capable of collaborating effectively with advanced technological systems while prioritizing sustainable development goals [6, 7]. This calls for the strategic integration of I5.0 principles – such as human-centeredness and sustainability – into teaching and learning processes [8, 9]. Existing research highlights the importance of developing comprehensive competency frameworks in higher and vocational education that

combine technical expertise with soft skills and ethical awareness [10, 11]. Globally, there is also a growing emphasis on reskilling and upskilling the current workforce as well as implementing adaptive learning systems to meet evolving industry demands [12].

### 2.2. Modern Models of Employee Competencies in the Global and Ukrainian Context

Employee competency models in the I5.0 environment differ significantly from those of Industry 4.0 (I4.0). While I4.0 primarily emphasized technical skills for operating automated systems, I5.0 prioritizes uniquely human abilities, including creativity, critical thinking, emotional intelligence, and ethical judgment [13]. Researchers typically classify I5.0 competencies into three main groups [8]:
- technological competencies;
- social and emotional competencies;
- sustainable development and ethical competencies.

These skills, often referred to as 21st-century competencies, are essential for employees to adapt, innovate, and collaborate effectively within hybrid human–machine work environments.

In the global context, I5.0 competency models emphasize deep knowledge of human–machine interaction, analytical skills for processing and interpreting big data, and holistic thinking that takes into account environmental and social impacts [14].

In Ukraine, where digital transformation intersects with complex socio-economic challenges, adapting these models is particularly critical. There is a pressing need to harmonize educational standards – especially in software and digital skills – with European and global I5.0 requirements. Emphasis should be placed on developing digital literacy at all levels and integrating ethical standards into professional practice, particularly in sectors involving critical technologies and post-conflict recovery [15].

The vocational education system plays a central role in preparing the workforce for I5.0, training skilled workers who engage directly with production systems. Notable advancements in this area include [16]:
1. Modernization of equipment in select vocational education institutions, enabling practical training with CNC machines, sensor systems, and Internet of Things (IoT) technologies.
2. Pilot projects introducing dual education programs, fostering closer collaboration with enterprises, and updating curricula accordingly.
3. Enhanced focus on developing foundational digital skills within training programs.

However, significant challenges remain:
1. The inertia of training programs, which adapt slowly to the rapidly evolving technological requirements of I5.0, resulting in a mismatch between labor market needs and the quality of workforce preparation [17].
2. A shortage of highly qualified instructors with I5.0 competencies, such as experience programming industrial cobots or working with predictive analytics [18].
3. Insufficient funding for large-scale modernization of material and technical resources and for implementing simulation technologies [19].
4. The absence of a unified national strategy for integrating I5.0 principles, particularly human-centered and sustainable development approaches, into the education system [20].

### 2.3. Technological Competencies

Technological competencies for I5.0 workers extend far beyond basic computer literacy. They emphasize the ability to collaborate effectively with intelligent systems and leverage digital tools to address complex, non-routine tasks [16].

In the I5.0 context, digital literacy encompasses not only proficiency with standard software but also data literacy, which involves the ability to collect, analyze, and interpret large volumes of data generated by intelligent manufacturing systems [21].

Working with AI and robotics is a central pillar of I5.0. A key competency involves interacting with cobots (collaborative robots), where the worker does not merely operate the machine but collaborates with it, adding a "human touch" to personalized production [11]. This requires knowledge of [22]:
1. Fundamentals of robot programming and configuration.
2. Principles of machine learning (ML) to understand AI decision-making processes and optimize system performance.
3. Sensor systems and their integration into production workflows.

These competencies not only enhance productivity but also improve workplace safety and adaptability, enabling humans to manage complex processes and make rapid decisions based on real-time data analysis [23].

For the effective training of technologically skilled workers, practical competencies must be integrated directly into the educational process. Recommended approaches include [24]:
1. Establishing training laboratories equipped with elements of Cyber-Physical Systems (CPS) and IoT devices that replicate real I5.0 production environments.
2. Employing VR/AR technologies to simulate complex operations and train technical maintenance of high-tech equipment without the risk of damage.
3. Implementing project-based learning, where students tackle real-world production challenges requiring the combined use of digital, robotic, and analytical tools.

### 2.4. Social and Emotional Competencies

In the era of I5.0, where routine technical tasks are increasingly automated, social and emotional competencies (soft skills) become especially valuable. The European I5.0 strategy identifies these competencies as central to human well-being [5]. They enable individuals to leverage their uniquely human traits – creativity, empathy, and complex problem-solving – in synergy with machine intelligence.
Teamwork evolves into the ability to operate effectively within cross-functional, hybrid teams that comprise both humans with diverse specializations and intelligent systems (AI assistants, cobots). Effective collaboration requires [25]:
1. Clear verbal and non-verbal communication to coordinate actions across complex production chains.
2. Facilitation and mediation skills to manage conflicts and ensure mutual understanding among different stakeholders, including engineers, operators, and AI systems.

Creativity is a key human advantage over machines. In I5.0, creativity is essential for [26]:
1. Developing personalized products and solutions (mass personalization).
2. Generating innovative approaches to process optimization that cannot be deduced solely by algorithms.
3. Designing holistic solutions to challenges arising at the intersection of technology, people, and environmental requirements.

The rapid pace of technological change demands that modern workers be highly adaptable and resilient, which constitutes one of the three pillars of I5.0. Adaptability involves the ability to quickly learn new technologies, modify work approaches, and perform effectively under uncertain conditions [27].

Lifelong learning is no longer simply a preference but a critical necessity. Enterprises and educational systems must cultivate the following in employees [28]:
1. Meta-skills: the ability to self-reflect, self-motivate, and plan one's own educational trajectory.
2. Intrinsic motivation to continuously update knowledge and qualifications.
3. Critical thinking to evaluate and filter information effectively in conditions of information overload.

## 2.5. Sustainable Development and Ethical Competencies

The I5.0 paradigm directly incorporates sustainable development goals and ethical standards into production processes, positioning industry as a responsible agent of social and environmental change [4].
Sustainable development as a competency encompasses [29]:
Environmental awareness – understanding the impact of professional activities on the environment, including carbon footprint, resource consumption, and waste management.

Circular economy skills – the ability to apply principles of recycling, repair, and reuse of materials within production processes.

Social responsibility – awareness of the societal impact of one's work, including considerations of equality, inclusiveness, and employee well-being.

I5.0 employees are therefore required not only to perform technological tasks but also to actively engage in environmental and social auditing processes, making decisions that prioritize long-term sustainability.

The increasing use of AI and big data in manufacturing introduces unprecedented ethical challenges, highlighting the need for ethical competencies. Workers in I5.0 environments must be prepared to [30]:
1. Ensure data privacy and security, particularly regarding the personal information of colleagues and customers.
2. Prevent algorithmic bias and discrimination by understanding how AI systems can produce biased outcomes.
3. Practice responsible use of robotics, adhering to ethical standards when interacting with cobots and other automated systems, including understanding liability in the event of malfunctions or accidents.

Ethical leadership and transparency are becoming essential requirements for all participants in the production process. Accordingly, vocational training programs must integrate professional ethics and the philosophy of technology to provide workers with a clear understanding of the moral dilemmas inherent in high-tech environments.

## 3. Methodology

### 3.1. Sample and Procedures

An empirical survey was conducted to assess the readiness of applicants and graduates of vocational education institutions in Ukraine to work under I5.0 conditions, as well as to evaluate the balance between human, technological, and sustainable components of their professional competencies.

The target group included senior students and recent graduates from various vocational education institutions across Ukraine. A total of 273 participants were surveyed, out of which 61% were students in the final stage of their studies and 39% were graduates from the past three years.

Data were collected through questionnaires and semi-structured interviews. The primary tool was an online survey administered via Google Forms, which ensured ease of access and respondent anonymity. The questionnaire consisted of five thematic sections aimed at assessing:
- technological competencies (digital literacy, use of new technologies, robotics, AI).
- social, communication, and emotional skills (teamwork, adaptability, communication).
- ethical and environmental competencies (attitudes toward sustainable development, professional ethics).
- general self-assessment of readiness to work in I5.0 conditions.
- suggestions for improving training content within the VE system.

In addition to the questionnaire, interviews with 15 respondents were conducted to broaden the analysis of specific findings. These interviews provided insights into participants' attitudes toward digital innovations, the perceived importance of soft skills, and their perspectives on the role of sustainable development in vocational education.

The collected data were summarized, systematized, and subjected to descriptive and comparative statistical analysis. By combining quantitative and qualitative approaches, the study was able to produce more reliable and nuanced conclusions regarding the readiness of vocational education graduates for I5.0 conditions.

### 3.2. Research Design and Conditions

The study employed a mixed-methods approach, combining quantitative and qualitative methods of data collection and analysis. This design was selected to provide a comprehensive assessment of the readiness of students and graduates of vocational education institutions to work in I5.0 conditions, considering both objective indicators of competency development and participants' subjective perceptions of their professional potential.

The quantitative phase involved an online survey, enabling data collection from a large sample (n = 273). The survey primarily consisted of closed-ended questions using a Likert scale, allowing for the statistical generalization of the results. Data were processed using descriptive statistics, including mean values, percentage distributions, and group comparisons.

The qualitative phase consisted of semi-structured interviews with a smaller group of respondents (n = 15), selected voluntarily from graduates of various specializations. This phase aimed to explore individual perspectives and experiences regarding the use of technology, the development of social and emotional skills, and the perceived role of sustainable development in professional growth.

Data collection was conducted online between April and June 2025 using digital tools such as Google Forms and Google Meet, which ensured participation from individuals from various regions of Ukraine. All participants took part voluntarily and were fully informed about the study's objectives, procedures, and confidentiality measures.

To assess the relevance of the findings to current labor market demands, a comparative analysis was performed, contrasting graduates' competencies with employer expectations as outlined in analytical reports and recommendations from the European Commission, OECD, and national educational studies.

This research design allowed for not only the identification of the current level of key competency development but also the formulation of directions for further modernization of vocational training, in line with the principles of human-centeredness, technological advancement, and sustainable development.

## 4. Data Analysis

The results of the survey and interviews allowed for a comprehensive assessment of the readiness of vocational education graduates to work in I5.0 conditions. The analysis focused on three main areas of competency: technological, socio-emotional, and ethical (sustainable development).

### 4.1. Technological Competencies

Quantitative survey results indicated that the majority of respondents exhibited an average to above-average level of digital literacy (Fig. 1).
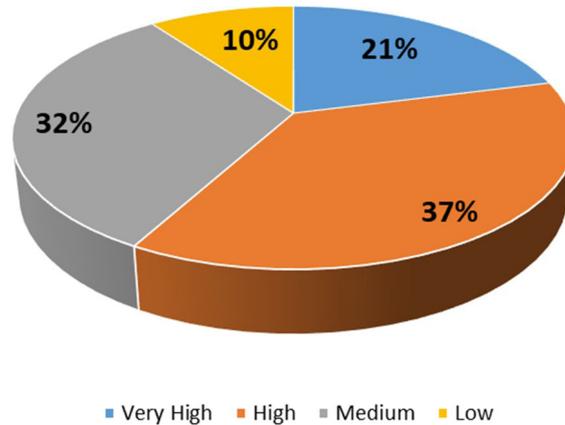
Fig. 1. Digital competency levels of VET graduates based on survey results
Source: authors' own work

Approximately 68% of respondents reported actively using digital tools in their studies or work (such as office software, online platforms, and mobile applications), whereas only 24% had experience with AI or automation technologies. This suggests a positive trend in the development of basic digital competencies, but highlights limited practical experience with the innovative technologies that characterize I5.0.

Regarding the adequacy of training programs, 58% of respondents indicated that their programs partially prepared them for the use of new technologies, 17% considered the training comprehensive, and 25% reported that the education process was inadequate and insufficient in its practical aspect.

Insights from interviews with graduates corroborated these findings, revealing that the main challenges emerge when transitioning from theoretical understanding of digital processes to their practical application in production settings.

### 4.2. Social and Emotional Competencies

Social and communication skills are recognized as a central component of the human-centered I5.0 paradigm. According to survey results, more than half of the respondents rated their communication skills as very high or high (Fig. 2).
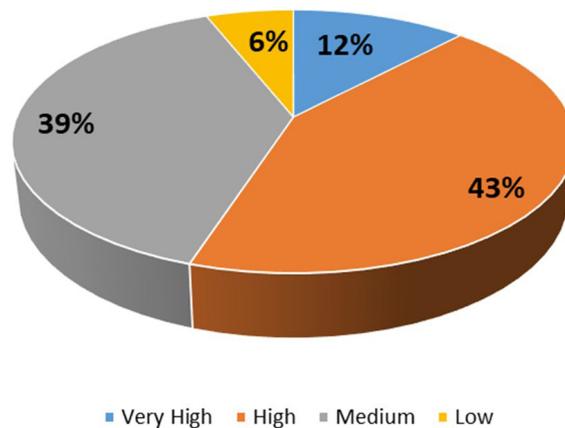


Fig. 2. Self-assessed social and communication skills of VET graduates
Source: authors' own work

Regarding teamwork skills, 64% of respondents reported feeling comfortable working in groups, while 22% occasionally encountered difficulties due to differing levels of responsibility or leadership.

Adaptability to change is identified as one of the most critical competencies in I5.0. More than half of respondents (53%) indicated that they adapt easily to new conditions and technologies, 31% adapt gradually, and 16% experience significant challenges.

Furthermore, 84% of respondents acknowledged continuous learning as an important or very important factor for professional development, reflecting a clear awareness of the necessity to cultivate soft skills to remain competitive in the modern labor market.

### 4.3. Ethical Competencies and Focus on Sustainable Development

Indicators in this category revealed a relatively high level of environmental and social awareness among respondents. Graduates demonstrated a strong understanding of the environmental aspects of their profession and partially considered the environmental impact of their activities (Fig. 3).
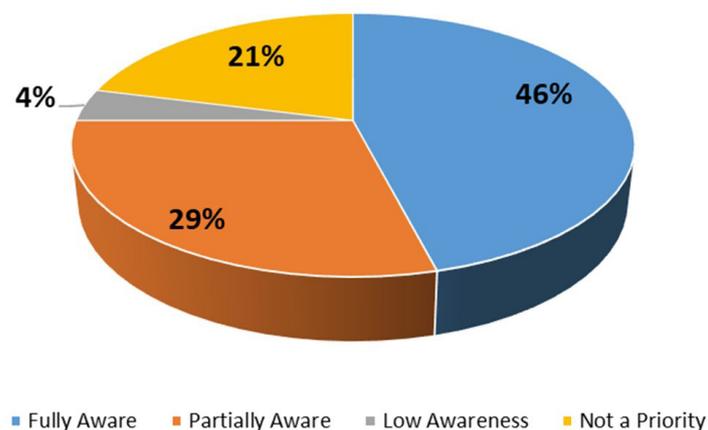


Fig. 3. Environmental and social awareness levels of VET graduates
Source: authors' own work

The majority of respondents (72%) expressed strong support for the principles of sustainable development, viewing them as a fundamental basis for the future professional environment. 18% held a neutral position, while 10% were unable to clearly articulate their stance.

Regarding ethical standards of professional conduct, 81% of graduates considered them to be very important, particularly in relation to safety, responsibility, and mutual respect within teams. However, only 28% indicated that ethics and sustainable development are systematically integrated into their curriculum, highlighting the need to strengthen the humanities component within vocational training programs.

**5. Discussion**

The results of the study indicate that modern students and graduates of vocational education institutions possess a certain level of readiness to work under I5.0 conditions; however, this readiness is characterized by uneven development of key competencies. On one hand, most respondents demonstrated a satisfactory level of digital literacy and basic technological skills, reflecting the effectiveness of traditional software training. On the other hand, the findings reveal insufficient practical experience with innovative technologies such as robotics, automated systems, and artificial intelligence. This underscores the need to integrate contemporary technological practices into educational programs, including laboratory work, workshops, and internships.

Graduates' social and emotional skills, particularly teamwork, communication, and adaptability to change, were found to be relatively well-developed. This aligns with the human-centered focus of I5.0, where effective interaction between people and technology is crucial for success. Nevertheless, the results suggest that some respondents require additional support in developing leadership and change management skills, which may influence their effectiveness in high-tech professional environments.

The study also highlights a high level of awareness among students and graduates regarding the environmental and social dimensions of professional activity, confirming that educational institutions are addressing the humanitarian and ethical aspects of training. However, the lack of systematic integration of sustainable development into practical training tasks limits graduates' ability to implement these principles in real-world professional contexts. This emphasizes the necessity of integrated approaches that combine technological competencies with ethical and sustainability standards.

Based on the findings, the following strategies are proposed to enhance the training of future specialists:
1. Strengthening the technological component – incorporating practical courses in robotics, AI, automation, digital modeling, and interaction with intelligent systems.
2. Development of social and emotional competencies – including training in teamwork, leadership, adaptability, and critical thinking.
3. Systematic integration of sustainable development and ethics – embedding environmental and social responsibility principles into project work and production practices.
4. Use of blended learning – combining online courses, practical laboratories, and enterprise-based internships to foster a comprehensive balance between people, technology, and sustainability.
5. Competency monitoring – regularly assessing the development of key competencies and comparing them with current I5.0 labor market requirements.

The study confirms that sustainable development principles and technologies are key factors in shaping the modern workforce. Their integration into the educational process enables the creation of a comprehensive competency model, in which individuals interact effectively with technology while adhering to ethical and environmental standards.

Overall, the findings affirm the relevance of the I5.0 concept for Ukrainian vocational education and highlight specific directions for its implementation to enhance graduates' competitiveness in the labor market.

**Limitations of the Study**

Despite the insights gained, this study has several methodological and practical limitations that should be considered when interpreting the findings. The total sample consisted of 273 students and graduates of vocational education institutions. This provides a certain level of representativeness; however, its size as well as sectoral and regional coverage remain limited. The study did not include all VE specialties nor cover all regions of Ukraine, which may affect the generalizability of the results across the entire vocational education system.

The primary data collection instrument was an online survey, which may limit the accuracy of self-assessed competencies due to the inherent subjectivity of responses. Additionally, the number of semi-structured interviews (n = 15) was relatively small, meaning that qualitative findings should be considered supplementary and may not fully represent the entire target group.

The limited availability of scientific literature on the implementation of I5.0 in vocational education makes comparative analysis difficult and complicates the establishment of clear national competency standards. Moreover, the long-term tracking of graduates' professional competencies is not systematically conducted, which constrains the evaluation of the sustained effectiveness of training programs.

Despite these limitations, the study provides valuable insights into the levels of technological, socio-emotional, and ethical competencies among students and graduates of vocational education. It also highlights key areas for improvement in training programs within the context of I5.0.

**6. Conclusions**

The study confirmed that current students and graduates of vocational education institutions exhibit a certain level of readiness to work under I5.0 conditions; however, this readiness is uneven across key competency areas.

In terms of technological competencies, graduates generally possess the basic digital skills required for routine professional tasks. However, their practical experience with innovative technologies such as AI, automation, and robotics remains limited, highlighting the need to strengthen hands-on technological training.

Regarding social and emotional competencies, teamwork, communication, and adaptability were identified as the most developed skills among respondents. Nevertheless, some graduates require further development in leadership and change management, which are critical for effective performance in dynamic, high-tech environments.

In terms of ethical and sustainable development competencies, the majority of respondents demonstrated a high level of awareness regarding the environmental and social aspects of professional activity. However, the lack of systematic integration of

sustainable development principles and ethical standards into practical training limits their implementation in professional settings.

Modern vocational education partially ensures a balance between people, technology, and sustainability, but gaps remain in the integration of technological and ethical components. Developing competencies that simultaneously encompass technology, social skills, and ethical awareness is a key task in modernizing education for I5.0.

For practical implementation, educational institutions are encouraged to integrate hands-on technology courses, soft skills training, and project-based tasks focused on sustainable development. Employers should support internships and collaborative projects with vocational institutions to enhance practical training. Additionally, the regular monitoring of competencies, combined with alignment to current labor market requirements, will facilitate the dynamic updating of educational programs.

Regarding future research, it is necessary to expand the sample size and include a broader range of regions in Ukraine to improve representativeness. Further studies should examine the practical integration of I5.0 technologies and sustainability principles into vocational education programs. Future research may also focus on evaluating the effectiveness of specific innovative teaching methods and their impact on the development of comprehensive competencies among modern workers.

## 7. Ethical Considerations

The study strictly adhered to ethical principles applicable when working with human participants. Confidentiality of survey and interview respondents was fully ensured. All personal data were stored in encrypted form, and the results of the analysis were reported only in aggregate, making it impossible to identify individual participants. Participation in the study was voluntary. Prior to the survey and interviews, respondents were fully informed about the study's objectives, structure, and potential implications. They retained the right to withdraw from the study at any stage without any negative consequences. During data collection, principles of safety and a comfortable communication environment were observed, particularly during online interviews. The study results were used exclusively for scientific and educational purposes, specifically to assess the level of competencies among students and graduates of vocational education institutions and to formulate recommendations for improving educational curricula in the context of I5.0. Any dissemination of data outside of these purposes was strictly prohibited, ensuring the ethical responsibility of the researchers toward participants.

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# NOWOCZESNY PRACOWNIK W KONTEKŚCIE PRZEMYSŁU 5.0: RÓWNOWAGA MIĘDZY CZŁOWIEKIEM, TECHNOLOGIĄ I ZRÓWNOWAŻONYM ROZWOJEM

## STRESZCZENIE

Artykuł analizuje gotowość kandydatów i absolwentów instytucji kształcenia zawodowego (WE) na Ukrainie do pracy w warunkach Przemysłu 5.0. Badania wynikają z pilnej potrzeby przejścia od paradygmatu Przemysłu 4.0, opartego na technologii, do modelu zorientowanego na człowieka, zrównoważonego i odpornego na kryzysy, który wymaga integracji nowych kompetencji. Głównym celem była ocena obecnego poziomu przygotowania studentów i absolwentów szkół zawodowych oraz ocena równowagi między komponentami technologicznymi, społeczno-emocjonalnymi i etycznymi (zrównoważony rozwój) w ich kompetencjach zawodowych. Zastosowano podejście mieszane, łącząc ilościową ankietę internetową (n = 273) z jakościowymi, częściowo ustrukturyzowanymi wywiadami (n = 15) ze studentami i absolwentami szkół zawodowych. Kluczowe ustalenia wskazują na nierównomierny poziom gotowości. Chociaż absolwenci wykazują podstawową znajomość technologii cyfrowych, ich praktyczne doświadczenie z innowacyjnymi technologiami, takimi jak sztuczna inteligencja i robotyka, pozostaje ograniczone. Z kolei umiejętności społeczne i emocjonalne – w tym praca zespołowa, komunikacja i zdolność adaptacji – okazały się stosunkowo dobrze rozwinięte. Pomimo wysokiego poziomu świadomości ekologicznej i społecznej wśród respondentów, zasady te nie są jeszcze wystarczająco zakorzenione w kształceniu praktycznym. Badanie wykazało luki w integracji elementów technologicznych i etycznych, co podkreśla potrzebę wzmocnienia praktycznych kursów technologicznych i systematycznego włączania zasad zrównoważonego rozwoju do programów nauczania w dziedzinie etyki zawodowej.

## SŁOWA KLUCZOWE

Przemysł 5.0, nowoczesny pracownik, kształcenie zawodowe, kompetencje, równowaga (ludzie, technologia, zrównoważony rozwój).