1.1. PROFESSIONAL AND PRACTICAL TRAINING OF FUTURE CONSTRUCTION PROFESSIONALS FOR INDUSTRY 5.0

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Based on a comparison of the purpose, objectives and main characteristics of the fourth industrial revolution (or Industry 4.0) and Industry 5.0, the requirements for the organisation of professional education of future specialists are revealed. The list of competences that will be most in demand in the labour market over the next five years is highlighted. The results of the analysis of the peculiarities of the organisation of professional and practical training of future specialists in the construction industry in vocational (vocational-technical) and professional higher education institutions in the context of the implementation of the Industry 5.0 concept are presented. Recommendations for improving the system of training of construction industry specialists in Ukraine are proposed.

Keywords: *professional education, professional training, Industry 5.0, professional-practical training, construction sector, professional competencies.*

1.1. ПРОФЕСІЙНО-ПРАКТИЧНА ПІДГОТОВКА МАЙБУТНІХ ФАХІВЦІВ БУДІВЕЛЬНОЇ ГАЛУЗІ ДЛЯ ІНДУСТРІЇ 5.0

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На основі порівняння мети, завдань та основних характеристик четвертої промислової революції (або Індустрії 4.0) та Індустрії 5.0 розкрито вимоги до організації професійної освіти майбутніх фахівців. Виділено список компетентностей, що будуть найбільш затребувані на ринку праці протягом наступних п'яти років. Представлено результати аналізу особливостей організації професійно-практичної підготовки майбутніх фахівців будівельної галузі в закладах професійної (професійно-технічної) та фахової передвищої освіти в контексті реалізації концепції Індустрія 5.0. Запропоновано рекомендації для вдосконалення системи підготовки фахівців будівельної галузі в Україні.

Ключові слова: *професійна освіта, професійна підготовка, Індустрія 5.0, професійно-практична підготовка, будівельна галузь, фахові компетентності.*

Professional-practical training of future specialists in the construction sector is of exceptional relevance in the era of Industry 5.0. In today's world, the construction sector is undergoing significant transformations under the influence of cutting-edge technologies. Industry 5.0 combines technological innovations with a human-centered approach, creating prerequisites for sustainable development, ecological awareness, and improved quality of life. For Ukraine, these processes open up new opportunities not only for increasing the efficiency of construction processes but also for training specialists capable of working within the technological revolution. Industry 5.0 opens doors for the integration of innovative technologies that radically change traditional approaches to construction. For future specialists in the construction sector during the Fifth Industrial Revolution, it is important not only to be aware of these tools but also to actively apply them in their practical activities.

The professional and practical training of future builders is one of the key prerequisites for the successful implementation of the tasks of modern vocational education. It aims to address urgent issues of state restoration and development, overcome global challenges, and ensure the rapid advancement of scientific and technological progress. Successful organization of professional-practical training for future specialists involves adapting educational and training programs to labor market demands, utilizing innovative teaching approaches, and implementing active cooperation with the construction business. Through the integration of theoretical knowledge with practical skills, future specialists will be able to effectively work with advanced technologies and fulfill tasks aimed at the sustainable development of the construction sector.

Industry 5.0, building upon the foundations of Industry 4.0, introduces new approaches to management and work organization. It creates opportunities for implementing cutting-edge technologies such as robotics, 3D printing, artificial intelligence (AI), Internet of Things (IoT) systems, the development of autonomous construction systems, blockchain, and more, in combination with human-centricity and the greening of production. Future builders must be prepared to work with robots for bricklaying or wall painting, operate drones to monitor construction sites, and utilize blockchain technology to ensure transaction transparency and the accuracy of data regarding buildings and structures. In the context of fostering an innovative culture, students must understand how to use modern technologies for contract management, study methods of logistics management, and efficient

utilization of construction materials and structures. In the construction sector, which is one of the critical components of the national economy, the implementation of Industry 5.0 tasks entails not only automation of production processes but also integration of solutions centered on human safety and well-being, introduction of new standards and technologies ensuring efficiency, eco-friendliness, and innovation in production and labor organization. The presented research sheds light on modern trends in the socio-economic development of the state, particularly the construction sector in the context of Industry 5.0, and identifies key directions for professional training of future qualified workers in construction specialties according to current economic needs.

The current stage of socio-economic development in our country is marked by the peak of Industry 4.0, although some enterprises still operate based on the principles of the Third Industrial Revolution, characterized by initial automation and the introduction of electronics. At the same time, the European Commission is already working on advancing Industry 5.0. The Fourth Industrial Revolution (or Industry 4.0) is an era where technologies such as artificial intelligence, online resources, automation, and robotics come together to create "smart factories" and optimize production processes. In Industry 4.0, computers and machines are focused on interaction and decision-making with minimal human intervention. This allows businesses to enhance efficiency, reduce costs, increase product quality, and adapt to market changes more rapidly. However, Industry 4.0, with its emphasis on technology and automation, often neglects the environmental impact of production and, in some ways, isolates humans from work processes. This leads to a rapid reduction in jobs, the destruction of natural resources, and a disruption of ecological balance.

1) at the same time, Industry 5.0 is a concept that envisions combining the power of modern technologies with people's ability for creative and innovative thinking. It focuses on placing humans at the center and utilizing technologies to support and enhance the quality of work. Industry 5.0 is directed towards ensuring balanced economic development, where technologies improve the quality of life, create new opportunities for business growth, and promote sustainable development of society as a whole. The goal of the Fifth Industrial Revolution (or Industry 5.0) is to unite innovative technological capabilities with human-centricity and the greening of production. Among the key objectives of Industry 5.0 are identified;

2) developing effective and balanced strategies to restore the potential of engineering personnel, science, and education at both the state and community levels;

3) introducing an innovative culture and organizing production where humans actively participate, realize their creative potential, and engage in continuous learning (Sobolevska, 2023).

New socio-economic realities affect not only the development of production and science but also foresee significant qualitative changes in the professional training of future skilled workers in construction. Considering that the foundational principles of Industry 5.0 involve constructive responses to economic and social challenges, strengthening the foundations of scientific and technical innovations, ensuring a systematic cycle of human resource training, knowledge, and capital for innovations, and the development of eco-oriented production processes and technologies, the primary task of the vocational (vocational-technical) education system is to ensure that the content, forms, and methods of professional training for future qualified workers meet the requirements of the modern economy while identifying the leading trends in its development.

According to the World Economic Forum's «The Future of Jobs Report 2025» (Leopold, 2025), it is predicted that over the next five years, the importance of technological competencies will grow most significantly. Competencies related to interaction with artificial intelligence and the analysis of large data sets lead the list of promising skills. This list is followed by the ability to work in a networked space, awareness of cybersecurity issues, and technological literacy. Creative thinking, stress resistance, flexibility in communication, and agility are also becoming increasingly important, along with diverse interests and the ability to engage in lifelong learning. The top ten most in-demand competencies also include leadership and social orientation, self-development skills, analytical thinking, and competencies related to environmental protection. At the same time, business companies are increasingly investing in retraining and upskilling programs for employees to maintain their professional abilities in accordance with rapidly changing economic demands.

Innovations recently introduced in the construction industry fully align with Industry 5.0 strategies, where the principles of sustainable development, resilience, value chains and ecosystems, societal needs orientation, circular economy, and equitable distribution of labor outcomes begin to dominate decision-making. Under such approaches, technologies

are merely tools for achieving sustainable development goals, which fundamentally distinguishes Industry 5.0 from the foundational principles of Industry 4.0, where the primary focus is on improving competitiveness and profitability through the application of new technologies (Sobolevska, 2023).

The main principles of Industry 5.0 in the construction sector are:

– Human-centricity, as in the context of Industry 5.0, humans become the center of all processes – from project development to building operation. Innovative technologies are intended to facilitate human work, reduce risks, and improve productivity. For instance, robotic systems can perform hazardous tasks that pose health risks, leaving humans to take on the role of coordinators;

– Sustainable development, which involves the use of environmentally friendly materials, reduction of energy consumption, and the implementation of solutions that promote waste minimization (Borovyk et al., 2021);

– Technological integration, particularly the use of IoT, AI, robotics, and 3D printing, is becoming a standard in the construction sector. This enables the automation of production processes, improves the accuracy of work, and optimizes costs. For example, IoT systems can monitor the condition of buildings in real-time, providing timely information for management (iOTJI, 2020).

Training specialists to work in the conditions of Industry 5.0 requires not only theoretical knowledge but also practical skills that enable the use of modern technologies, adaptation to rapid changes, and ensuring sustainable development of the construction sector (Alyoshyna, 2025). Serious challenges for professional and practical training of specialists in the construction sector in modern conditions include:

– Rapid technological development, as new technologies emerge annually, changing approaches to construction. For example, the use of 3D printing to create building structures, which has become one of the most innovative technologies, allows for the creation of structures with minimal material and time costs (Buduemo, 2023);

– Insufficient funding, as modernizing the educational process requires significant investments, which are often inaccessible to many educational institutions, complicating the training of qualified personnel for Industry 5.0. According to the Ministry of Education of Ukraine, in 2023, only 40% of vocational (technical) education institutions were able to receive funding to update equipment (Markovets, 2024);

– The training and professional development of teachers are essential, as organizing the educational process and working with modern technologies such as BIM, VR, or robotics require appropriate knowledge and skills from educators.

Due to the rapid development of innovations in construction, the vocational and practical training of specialists in the construction sector requires innovative approaches. Modern technologies and methods allow students to develop practical skills in conditions that closely resemble real production environments. In particular, this involves:

– utilization of virtual reality technologies, considering that simulators based on virtual reality have become indispensable tools in the training of builders. For example, during the design of buildings, students can model various structures and test them in simulated environments, analyzing their stability and functionality. When organizing vocational and practical training, virtual reality technologies allow students to work with construction mechanisms without health risks;

– application of Building Information Modeling (BIM) systems, which transform approaches to construction and project management. Based on BIM technologies, students learn to work with digital building models, calculate materials and costs, and determine the life cycle of structures (DedalSoft, n.d.);

– the implementation of robotics is extremely important in the training of specialists. Future builders learn to work with specialized robots, such as those used for bricklaying or applying plaster, and master the basics of operating automated mechanisms on construction sites (VSN, 2024);

– use of 3D printing in construction, which is actively employed for the creation of both individual elements and entire structures. 3D printing technologies reduce material and time costs in construction. As a result, vocational education institutions are actively integrating specialized courses into the educational process, enabling students to properly master these technologies (Buduemo, 2023).

As previously mentioned, one of the key components of implementing the concept of Industry 5.0 is the greening process and the development of environmental awareness. For the construction sector, this implies the adoption of solutions that minimize the harmful impact on the environment caused by construction activities. In this context, the professional and

practical training of future specialists should include the development of ecological competence to ensure the sustainable development of the industry. The components of ecological competence include:

1) *Energy efficiency capabilities implemented in the design of modern buildings*. Future specialists should learn to design and install solar panels, heat pumps, and other renewable energy sources; and work with intelligent energy management systems that reduce energy consumption (European Commission, n.d.);

2) *The ability to use environmentally friendly materials*. Sustainable development technologies involve the active use of secondary materials, such as recycled concrete, bio-based materials made from agricultural waste, fiberglass, etc. The content of relevant educational courses should include familiarizing students with the properties of these materials and the specifics of their use in implementing construction projects. (Ecodoma, n.d.);

3) *Knowledge of circular economy and waste management*, since modern construction generates significant amounts of waste that can be recycled. Future specialists in the construction sector need to study the principles of the circular economy, methods for sorting and recycling waste for its effective reuse (Masterson, 2024);

4) *Knowledge of environmental standards and certification*. International environmental standards such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) serve as the foundation for evaluating buildings. Future specialists should learn the principles of certification and methods for integrating these requirements into construction projects (Nerukhomi, 2024).

In addition to technical knowledge, specialists in the construction sector must develop psychological readiness to work in the conditions of Industry 5.0. This includes creativity – the ability to find unconventional solutions to complex problems; stress resistance, meaning the capacity to work in a fast-changing environment; and communication skills, the ability to interact effectively within a team and with clients. To develop the mentioned abilities of future builders, vocational training programs should include interactive training sessions and simulations of real production scenarios.

Global practices in workforce training for the construction sector demonstrate examples of effective integration of technologies, innovative teaching methods, and sustainable development. For instance, Germany is among the leaders in implementing dual education, which combines theory and practice and is characterized by close collaboration with businesses. Students spend up to 50% of their time at enterprises, enabling them to gain practical experience. Training centers are equipped with technology used in real-world operations. This approach prepares graduates for the challenges of Industry 5.0 and equips them to work with innovative solutions (Rindfleisch & Manning-Fortman, 2020).

Finland and Sweden place significant emphasis on environmental education for builders. Key elements of this system include eco-oriented construction and the use of sustainable materials. Students study methods for designing "green" buildings, with particular attention paid to recycling and reusing waste. This experience enables graduates to develop projects that meet sustainable development requirements (Hafez et al., 2023).

In the United States, educational programs aimed at utilizing advanced technologies in construction are actively developing. Educational institutions collaborate with technology companies. For example, AutoDesk conducts training sessions for students on the use of software. Courses are introduced that enable future builders to create complex structures using 3D printing (TEG, n.d.). These initiatives promote technological literacy and readiness to work with innovations.

Singapore is renowned for its approach to the digitalization of the construction sector, with active use of BIM (InfoBud, n.d.). All projects must be presented in digital format. Training centers equipped with virtual reality facilities allow students to undertake simulations for honing their design and construction skills. This prepares professionals to work confidently in digital environments.

The presented international experience confirms that the rapid development of science and industrial innovations requires achieving the goals and outcomes of professional training through continuous updating of educational content, contextual pedagogical interaction, designing professional activity processes, developing algorithms for performing production-technical functions, and implementing practice-oriented learning.

To achieve the objectives of vocational education in the rapidly changing innovative economy, it is critically important for the leadership of vocational (technical and vocational) education institutions to establish close ties with construction organizations and business entities in the construction sector. This includes involving leading industry specialists to define the content of educational standards, develop educational and training programs, and conduct lessons, workshops, production training sessions, internships, and final qualification assessments for graduates.

To ensure the relevance and integration of professional training for future qualified workers in the construction sector, in line with the requirements of modern production, it is advisable for vocational education institutions to develop flexible educational pathways that enable lifelong learning, support future graduate employment, and conclude long-term cooperation agreements with various construction enterprises. These agreements should be based on public-private partnerships and other forms of socio-industrial interaction.

Conclusions. The experience of organizing theoretical training and practical work for future skilled workers in the construction field proves that the use of modern methodological approaches in education enables the rapid improvement of the process of developing professional competencies in students. Moreover, methodological support and the implementation of practical training under the guidance of leading experts in their field play a key role in preparing future qualified workers in the construction industry.

Based on the analysis of international practices and current challenges associated with the development of Industry 5.0, the following recommendations can be made to improve the system of training construction industry professionals in Ukraine:

1. *Integrate the latest technologies into the curriculum*. Ukrainian educational institutions should more actively implement innovative solutions that are already successfully used in international practice:

– use of BIM technologies for building modelling and project management;

– introduction of VR simulators to practice construction processes in a safe environment;

– training in robotics to automate construction processes.

With the growing role of digitalization, educational institutions can establish digital campuses and intelligent learning platforms that provide students with access to online courses and resources, virtual laboratories for practicing practical skills, and interactive platforms that utilize AI to personalize the learning process.

2. *Development of Dual Education*. The introduction of a dual education model, which combines learning in educational institutions with practical experience in enterprises, helps students develop practical skills that meet employers' requirements and enhance graduates' readiness to fulfill their job responsibilities in the workplace. This approach is successfully implemented in Germany and can be adapted to meet the needs of Ukraine's construction industry. To make specialist training even more practice-oriented, it is advisable to establish long-term cooperation agreements between educational institutions and construction companies. Such agreements may include the joint development of educational standards, curricula, and training programs, the organization of internships for students in real construction environments, as well as conducting training sessions and master classes by practicing professionals.

3. *Improvement of environmental training*. Taking into account international approaches to sustainable economic development, Ukrainian vocational education institutions should consider including the following in their educational programs:

– Courses on energy efficiency and ecological design;

– Training in the principles of circular economy and construction waste recycling;

– The use of environmentally friendly materials in real projects during practical training.

4. *Development of Emotional Intelligence*. Solving complex problems in construction requires the interaction of specialists from various fields. Emotional intelligence skills are becoming key for successful collaboration with colleagues and clients. Students should master methods of effective team communication, conflict resolution techniques, approaches to building trust within a team, ways to maintain motivation under stress, and strategies for task and role distribution based on the competencies and qualifications of each team member.

5. *Collaboration with International Partners*. To improve the workforce training system, it is advisable to: enhance the participation of Ukrainian educational institutions in international exchange programs, such as Erasmus+, which will allow them to adopt the experience of European countries; establish international educational platforms for joint learning by students and educators. Integration into international educational programs, particularly through participation in Erasmus+ programs and the joint implementation of projects with foreign universities and companies, will enable students to familiarize themselves with the best practices in the field.

6. *Investing in the Training and Professional Development of Educators*. The development of educators' professional skills is essential for the successful implementation of pedagogical changes. This includes conducting training sessions on working with advanced technologies such as BIM, VR, and 3D printing; collaborating with international experts for experience exchange.

7. *Utilizing Big Data Technologies for Economic Forecasting*. Big Data technologies can be used to analyze the demand for specialists in the construction industry, allowing for the updating of educational programs to meet labor market needs and optimizing student recruitment processes. Construction companies actively use «Big Data» to streamline processes. Students should study methods of data collection and analysis, as well as forecasting techniques, such as estimating project completion timelines or cost assessments.

The Economy of Industry 5.0 is based on three fundamental components: human-centricity (fostering talent development, diversity, and empowerment), resilience (focusing on robust and adaptive technologies), and sustainability (a process of structurally building the economy in accordance with the needs of balanced development of production, the social sphere, population, the natural environment, and technological and social progress). Its concept envisages the integration of innovative technologies with people's ability for creative and innovative thinking (Yashchuryk & Zhmuryk, 2023).

The central focus of Industry 5.0 transformations is the human being and the use of technologies to support and improve the quality of work, with significant attention given to education, retraining, and skill development. This ensures that people can effectively use new technologies and adapt to

changes in the production environment. The implementation of these principles in the vocational education system will create favorable conditions for training modern specialists to meet the urgent needs of the national economy, particularly qualified workers in the construction industry.

Thus, the development of Industry 5.0 is transforming approaches to education and creating new opportunities for professional training. Educational institutions and enterprises must collaborate to address contemporary challenges and prepare professionals for the rapidly changing environment of the construction sector.

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